CEPT Report 63

Report from CEPT to the European Commission in response to the Mandate

"To undertake technical studies regarding the possibility of making the usage of the network control unit (NCU) optional onboard MCA enabled aircraft"

Report approved on 18 November 2016 by the ECC

0 EXECUTIVE SUMMARY

This CEPT Report considers technical studies assessing the possibility of making the usage of the Network Control Unit (NCU) optional for Mobile Communications onboard Aircraft (MCA). The Report has been prepared in response to a Mandate from the European Commission [1] to verify that a MCA configuration without an NCU is sufficient, or not, to guarantee a reasonable protection against interference and signalling issues to and from terrestrial wireless telecommunication systems. The term “reasonable” is considered in light of “real life operations keeping account of the fleet mix (MCA and non MCA equipped aircraft, number of mobile terminals which remain operational in non MCA equipped aircraft, etc.).”

0.1 BACKGROUND

The existing regulatory framework consists of a connectivity part (1800 MHz for GSM & LTE and 2100 MHz for UMTS) and an NCU part which ensures that mobile service ground networks in various frequency bands (currently 450 MHz, 800 MHz, 900 MHz, 1800 MHz, 2100 MHz and 2600 MHz) are not visible to User Equipment onboard the aircraft. User terminals onboard MCA equipped aircraft will not attempt to connect to ground based mobile networks, since they can only connect to the network onboard, and can be instructed to always operate with minimum transmit power. Both aspects facilitate the coexistence with mobile communications networks on the ground. Out of 30,000 commercial flights in Europe each day, 2-3% are equipped with MCA.

New frequency bands are regularly allocated to mobile services and this leads to a requirement to regularly upgrade the NCU. Contrarily to the ground mobile network, any change to radio equipment onboard an aircraft is subject to a lengthy aviation certification process. Recognising that there is a need to ensure continued coexistence with mobile communications networks on the ground, it is nonetheless acknowledged that enabling MCA systems without an NCU could simplify the regulatory framework, simply their development, and significantly reduce their cost.

On 24 September 2014 the European Aviation Safety Authority (EASA) adopted Decision 2014/029/R [2] which makes it possible for European airlines to allow passengers to use their Personal Electronic Devices (PEDs) in transmitting mode during all phases of flight. There is a requirement for PEDs to be in “airplane mode”, on non-equipped aircraft. This new EASA regulation is equally valid for non-MCA equipped and MCA equipped European aircraft.

This EASA Decision is focussed on the aeronautical safety considerations with the use of the PEDs onboard aircraft, and does not consider radio frequency compatibility issues with other applications or services. The EASA Decision therefore does not change the regulatory process for authorising connectivity services onboard aircraft and the spectrum regulatory framework in place. Indeed, the MCA services provider shall comply with the regulatory framework.

0.2 TECHNICAL STUDIES

The studies address the potential for interference of MCA operations without an NCU to ground based mobile communications networks for the different technologies and frequency bands as described below.

Table 1: Technologies and frequency bands considered

Assumed Technology	Frequency band (MHz)	Uplink (UL) BS receive MS transmit (MHz)	Downlink (DL) BS transmit MS receive (MHz)	Duplex mode
LTE	450	450-460	460-470	FDD
LTE	700	703-733	758-788	FDD
LTE	800	832-862	791-821	FDD
GSM, UMTS, LTE	900	880-915	925-960	FDD
GSM, LTE	1800	1710-1785	1805-1880	FDD
UMTS, LTE	2100	1920-1980	2110–2170	FDD
LTE	2300	2300-2400		TDD
LTE	2600	2500-2570	2620-2690	FDD
		2570-2620		TDD
LTE	3500	3400-3600		TDD
LTE	3700	3600-3800		TDD

These technical studies considered the ability of User Equipment onboard an aircraft to connect to a ground based base station (Minimum Coupling Loss (MCL) analysis), and assesses the impact of visibility of multiple ground based base stations on the airborne User Equipment receiver to assess whether this is likely to be sufficient in practice to prevent a usable connection with a ground based base station being made (signal to Interference plus Noise (SINR) analysis). The impact of visibility of multiple ground based base stations on the onboard User Equipment's receiver has not previously been considered in EC Decision 2013/654/EC [6].

The MCL analysis concluded that visibility of both uplink and downlink transmissions results in registration of User Equipment onboard with Mobile Communication network on the ground being possible in GSM 900 MHz and 1800 MHz, UMTS 900 MHz and 2100 MHz and for LTE 450 MHz, 700 MHz, 800 MHz, 900 MHz at all altitudes, and for 1800MHz at 3000 m altitude. Registration to the ground network is not feasible for LTE 1800 MHz at 4000 m, and for any LTE operations in the 2100 MHz and all higher frequency bands at any altitude from 3000 m and above.

The SINR analysis generally concludes that no successful registration of User Equipment onboard the aircraft is possible in any of the GSM and LTE frequencies considered. However, under specific circumstances, such as edge of network coverage (for example coastlines), the analysis indicates that connectivity may be possible. For UMTS frequency bands considered, the analysis indicates that successful registration of user equipment onboard is possible. At 10 km, however, the signal levels received onboard are close to the SINR limit of the User Equipment.

This analysis was corroborated using real life data captured in the French macro cell deployment database and flight information from Flightradar24[1] for three domestic French flight paths, to derive the signal level received by User Equipment onboard aircraft.

In all cases the technical analysis considered that the radio signals to and from the aircraft cabin were attenuated by 5 dB by the aircraft skin. This assumption is consistent with previous studies of this kind,

[1] www.flightradar24.com

however, aircraft structures with higher attenuation will reduce the likelihood for interference to ground based mobile communication networks.

The interference analysis concluded that degradation of the capacity in UMTS ground networks will occur. The extent of that interference will vary according to interference environments (for example, network response, traffic model and distribution, UE deployments, terrain, etc.).

Moreover, future technologies related to 5G would likely involve frequency and time multiplexing access schemes for the transmission and the reception of UE and BS, similarly to GSM and LTE, unlike UMTS. Without precluding the frame structure, the waveform, the signalling procedures applicable to 5G systems, it can be expected, therefore, that the results of the studies for future 5G technologies would be similar to the LTE case. If this generally accepted assumption is not valid, further studies should be undertaken to assess the possible interference from the aircraft onto the ground mobile network (and on other services similar to what was carried out in CEPT Report 48).

0.3 CONCLUSIONS AND RECOMMENDATIONS

CEPT's studies have concluded that MCA operations without an NCU are sufficient to guarantee a reasonable protection against resulting interference and signalling issues to and from terrestrial GSM and / or LTE wireless telecommunication systems. Future technologies related to 5G would likely involve frequency and time multiplexing access schemes for the transmission and the reception of UE and BS, similar to GSM and LTE. In consequence, no NCU would be needed when such 5G terrestrial networks operate.

For UMTS systems, the studies conclude that an NCU is necessary to prevent connection of User Equipment onboard to mobile communications networks on the ground, and that the resulting connection will cause a partial and temporary reduction in capacity for the connecting and neighbouring ground based cells.

It is recommended, therefore, that the regulatory framework be updated to reflect that the usage of the NCU is made optional for all frequency bands where GSM and LTE are in operation.

The different results for GSM / LTE and UMTS can be explained by the different protection criteria for interference for the different technologies.

NCUs operating in other frequency bands other than UMTS under the current framework should respect the maximum e.i.r.p limits set in CEPT Report 16 [3] and CEPT Report 48 [4]. It is proposed to invite MCA operators to stop current NCU operation at 2.6 GHz wherever possible. The current deadline in the EC framework for the mandatory usage of the NCU at 2.6 GHz is no longer required.

For frequency bands where UMTS is in operation, User Equipment onboard should be prevented from attempting to access networks on the ground. This could be ensured:

- by the inclusion of a Network Control Unit (NCU), which raises the noise floor inside the cabin in mobile receive bands;

  and/or
- through aircraft fuselage shielding to further attenuate the signal entering and leaving the cabin.

CEPT proposes a relevant update of the technical annex of the EC framework on MCA (see Annex 6), Decisions 2008/294/EC [5] and 2013/654/EC [6].

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

Abbreviation	Explanation
3GPP	3rd Generation Partnership Project
ac-BS	Aircraft based Base Station
ac-MS	Aircraft based Mobile Station
ARQ	Automatic Repeat request
AWGN	Additive White Gaussian Noise
BS	Base Station
CDMA	Code Division Multiple Access
CEPT	European Conference of Postal and Telecommunications Administrations
CPICH	Common Pilot Channel
DL	Downlink
EASA	European Aviation Safety Agency
EC	European Commission
ECC	Electronic Communications Committee
EFIS	European Frequency Information System
e.i.r.p.	Equivalent Isotropic Radiated Power
ETSI	European Telecommunications Standardisation Institute
EU	European Union
FDD	Frequency Division Duplex
FSS	Fixed Satellite Service
g-BTS	Ground based Base Transceiver Station
g-MS	Ground based Mobile Station
GSM	Global System for Mobile Communications
ITU-R	International Telecommunication Union – Radiocommunication sector
LOS	Line Of Sight
LTE	Long Term Evolution
MCA	Mobile Communications onboard Aircraft
MCL	Minimum Coupling Loss
MIB	Master Information Block
MS	Mobile Station

Abbreviation	Explanation
NCU	Network Control Unit
OFDM	Orthogonal Frequency Division Multiplex
PBCH	Physical Broadcast Channel
PCFICH	Physical Control Format Indicator Channel
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PED	Personal Electronic Device
PLMN	Public Land Mobile Network
PRACH	Physical Random Access Channel
PSS	Primary Synchronisation Signal
QoS	Quality of Service
RE	Resource Element
RRC	Radio Resource Control
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
RSPP	Radio Spectrum Policy Programme
SDL	Supplementary Downlink
SEAMCAT	Spectrum Engineering Advanced Monte Carlo Analysis Tool
SINR	Signal to Inference plus Noise Ratio
SSS	Secondary Synchronisation Signal
TDD	Time Division Duplex
TPC	Transmit Power Control
T-PED	Transmitting Personal Electronic Device
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunications System
WIMAX	Worldwide Interoperability for Microwave Access

1 INTRODUCTION

An MCA system is composed of two pieces of equipment: one or more base stations and a Network Control Unit (NCU). The NCU is designed to ensure that signals transmitted by ground-based mobile systems are not detectable by the User Equipment within the aircraft cabin and so that user terminals can only register to the onboard base station which will set the transmit power level of the device according to the relevant MCA framework. The following two CEPT reports address the technical compatibility and requirements:

- CEPT Report 16 (March 2007) [3] has provided the CEPT investigation on the operation of the MCA system at a height of at least 3000 m above ground level in the 1800 MHz frequency band (1710-1785 MHz for uplink (terminal transmit, base station receive) / 1805-1880 MHz for downlink (base station transmit, terminal receive)). This report led to the adoption of the EC Decision 2008/294/EC [5].
- With the wide deployment of new mobile technologies, CEPT Report 48 (March 2013) [4] has provided new investigations on the technical impact on ground-based public network of introducing a new mobile communication service onboard aircraft based on UMTS or LTE technologies operating at height of at least 3000 metres above ground in the 1800 MHz frequency band (1710-1785 MHz for the uplink and 1805-1880 MHz for the downlink) and in the 2100 MHz frequency band (1920-1980 MHz for uplink and 2110-2170 MHz for downlink) for UMTS. This report was followed by the adoption of the EC Decision 2013/654/EC [6].

Nevertheless, new frequency bands are regularly allocated to mobile services and this leads to a regular upgrade of the NCU. Contrarily to the ground mobile network, any change onboard an aircraft is subject to a lengthy aviation certification process.

Enabling MCA systems without an NCU could simplify the regulatory framework. On the other hand there is a need to ensure that coexistence with mobile network is properly ensured.

This CEPT Report is the response to the EC Mandate issued by the European Commission to undertake technical studies regarding the possibility of making the usage of the NCU optional onboard MCA enabled aircraft (see Annex 1) [1]. The Mandate required that CEPT undertook studies to determine the possibility of making the NCU onboard MCA equipped aircraft optional.

Specifically CEPT was tasked with determining that an MCA configuration without NCU is sufficient to guarantee a “reasonable” protection against interference and signalling issues to and from terrestrial wireless telecommunication systems. The term "reasonable" must be seen in the light of "real life operations" keeping account of the fleet mix (MCA and non-MCA equipped aircraft, number of mobile terminals which remain operational also in non MCA equipped aircraft, etc.).

Additionally, the mandate required that the general and specific policy objectives of the RSPP, such as effective and efficient spectrum use and the support for specific Union policies be given utmost consideration by CEPT, and in implementing this mandate to take utmost account of EU law applicable and support the principles of service and technological neutrality, non-discrimination and proportionality insofar as technically possible.

Out of 30,000 commercial flights in Europe each day, only 2-3% are equipped with MCA.
This report describes the conclusions reached by the CEPT in response to the EC mandate on MCA.

2 CURRENT REGULATORY FRAMEWORK

2.1 INTRODUCTION TO CURRENT MCA REGULATORY FRAMEWORK

This section refers to current MCA regulatory framework from a radio communication perspective and to the new EASA regulation on aeronautical safety (non-radio) related to the use of Transmitting-Portable Electronic Devises (T-PEDs)[2] during any flight phase.

2.1.1 MCA Connectivity bands

The current regulatory framework allows for MCA operations in the frequency bands identified in Table 2 as MCA connectivity bands.

Table 2: MCA connectivity bands

	MCA Connectivity Bands
ac-BS (mobile networks base station onboard aircraft)	1710-1785 MHz (uplink)/ 1805-1880 MHz (downlink) (GSM1800, LTE1800) 1920-1980 MHz (uplink)/ 2110-2170MHz (downlink) (UMTS2100)

2.1.2 MCA NCU bands

Table 3 lists the frequency bands operated by the MCA NCU to remove, where needed, visibility of the ground-based mobile network, whilst the power level of the NCU is sufficiently low to avoid interference to these networks.

Table 3: CA Controlled bands

	NCU frequency bands / ground-based mobile technologies as stated in the EC Decision (2013/654) [6]
NCU Frequency band	460-470 MHz (CDMA2000/FLASH OFDM) 791-821 MHz (LTE) 921-960 MHz (GSM, UMTS, LTE , WIMAX) 1805-1880 MHz (GSM, UMTS, LTE, WIMAX) 2110-2170 MHz (UMTS, LTE) 2570-2620 MHz (LTE , UMTS, WIMAX) 2620-2690MHz (UMTS, LTE)

CEPT noted that the EC framework requires that MCA systems provide an NCU in 2600 MHz band from 1st January 2017.

2.2 NEW EASA REGULATION

On 24 September 2014 the European Aviation Safety Agency (EASA) adopted Decision 2014/029/R [2] which makes it possible for European airlines to allow passengers to use their Personal Electronic Devices

[2] T-PEDs – for example mobile devices (mobile phones, laptops, tablets).

(T-PEDs) in transmitting mode during all phases of flight i.e. without the need to be in “airplane mode”, on non-equipped aircraft. In the context of this report T-PEDs are ac-MS (mobile networks User Equipment onboard aircraft).

This EASA Decision is focused on the aeronautical safety considerations with the use of the T-PED onboard aircraft, and does not consider radio frequency compatibility issues with other applications or services as this is out of their scope.

The EASA Decision therefore does not change the radio regulatory process for authorising connectivity services onboard aircraft and the spectrum regulatory framework in place. The MCA services provider shall comply with the regulatory framework as defined in the EC Decision 2008/294/EC [5] which was amended by the EC Decision 2013/654/EC [6].

3 GROUND MOBILE NETWORKS - TECHNOLOGIES AND FREQUENCY BANDS CONSIDERED

CEPT has addressed the potential for interference of MCA operations without an NCU to ground based mobile networks for different technologies and frequency bands as described below.

Table 4: Technologies and frequency bands considered

Assumed Technology	Frequency band (MHz)	Uplink (UL) BS receive MS transmit (MHz)	Downlink (DL) BS transmit MS receive (MHz)	Duplex mode
LTE	450	450-460	460-470	FDD
LTE	700	703-733	758-788	FDD
LTE	800	832-862	791-821	FDD
GSM, UMTS, LTE	900	880-915	925-960	FDD
GSM, LTE	1800	1710-1785	1805-1880	FDD
UMTS, LTE	2100	1920-1980	2110–2170	FDD
LTE	2300	2300-2400		TDD
LTE	2600	2500-2570	2620-2690	FDD
		2570-2620		TDD
LTE	3500	3400-3600		TDD
LTE	3700	3600-3800		TDD

In Europe the 450 MHz band is not harmonised at ECC or EC level.

The 700 MHz band has been harmonised in CEPT ECC and is currently under finalisation at EC level.

The 1452-1492 MHz band is harmonised for SDL in Europe and is not relevant to MCA.

The 2300-2400 MHz band has been harmonised in CEPT ECC and is currently under consideration at EC level.

The 3400-3800 MHz band is harmonised for mobile networks and used on a non-exclusive basis by mobile networks, fixed service and FSS earth station in Europe.

Although the 2570-2620 MHz band is defined as a TDD band, there is some consideration within the 3GPP to use it as a SDL band.

For more information on relevant EC Decisions / ECC decisions: please consult EFIS (www.efis.dk)

CEPT considers that the technologies listed in Table 4 are the usual technologies in operation in those bands.

CEPT is using these assumptions for the further studies. The current authorisations in force are mainly technology neutral in these bands.

4 ANALYSIS

4.1 CONNECTIVITY ANALYSIS

This section addresses the ability of a user terminal onboard an aircraft to connect to a ground based base station (MCL analysis), and assesses the impact of visibility of multiple ground based base stations on the airborne user terminal receiver to assess whether this is likely to be sufficient in practice to prevent a usable connection with a ground based base station being made (SINR analysis).

The impact of visibility of multiple ground based base stations on the onboard user terminal's receiver has not previously been considered in EC Decision 2013/654/EC [6].

4.1.1 MCL analysis

Before analysing the impact of visibility of multiple base stations on an onboard user terminal's ability to connect to a ground based base station, minimum coupling loss (MCL) modelling has been undertaken to examine the variation of the received power at the airborne user terminal as a function of the angle above the base station transmit antenna horizon. For an assumed airborne platform altitude, calculations have been performed by taking into account the worst case elevation angle for the on ground receive calculating the received power at the airborne user terminal input by taking account of the ground based base station transmit antenna gain towards the airborne user terminal receiver and the path loss. The worst case elevation angle for the bands below 1 GHz was assumed to be 57 degrees and for the bands above 1 GHz the worst case elevation angle was assumed to be 37 degrees.

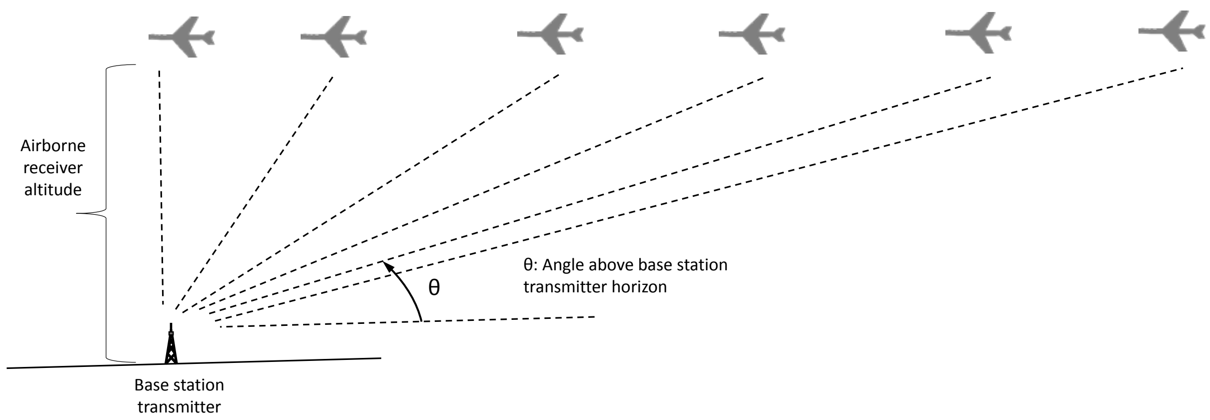

Figure 1: Scenario for received power variation at the airborne user terminal receiver

It is assumed that the airborne receiver operates at altitudes of 3, 5, and 10 km above ground. The base station antenna is assumed to be at 30 m height and 3 degrees down tilted. The path loss is assumed to be free space. The base station antenna pattern is based on Recommendation ITU-R F.1336-4 [9] and the airborne user terminal antenna pattern is assumed to be isotropic

As mentioned earlier, the results show the variation of the received power at the airborne user terminal as a function of the angle above the base station transmit antenna horizon. The received power levels are compared against the airborne user terminal receiver sensitivity to identify the angle above the base station transmit antenna horizon corresponding to the key alignment where the margin above the receiver sensitivity, hence the likelihood of establishing a sustainable ground-to-air link, is maximum.

4.1.2 Scenario 1-Downlink

The received power (dBm) at the user equipment onboard aircraft is:

$$P_{rec\,ac-MS} = e.i.r.p._{g-BTS} - L_{Aircraft} - L_{Prop} - BL_{ac-MS} + G_{ac-MS} \tag{1}$$

where:

- $e.i.r.p._{g-\mathrm{BTS}}$: e.i.r.p. of the signal radiated by the g-BTS, in the direction of the aircraft (dBm);
- $L_{Aircraft}$: Attenuation due to the aircraft (dB);
- L_{Prop} : Propagation loss between g-BTS and aircraft (free space path loss model) (dB);
- BL_{ac-MS}: Body loss of ac-MS (dB);
- G_{ac-MS} : Antenna gain of the ac-MS (dBi).

With resulting margin for the uplink:

$$M_{ac-MS} = S_{ac-MS} - P_{rec\,ac-MS} \tag{2}$$

where:

- S_{ac-MS}: Receiver sensitivity of the user equipment onboard aircraft (dB).

Note if the margin is positive, it means that the signal received by the airborne User Equipment is below its sensitivity.

4.1.3 Scenario 2-Uplink

The received power (dBm) at the ground terrestrial base station is:

$$P_{rec\,g-BTS} = e.i.r.p._{ac-MS} - L_{Aircraft} - L_{Prop} - BL_{ac-MS} + G_{g-BTS} \tag{3}$$

where:

- $e.i.r.p._{ac-MS}$: e.i.r.p. of the signal radiated by the ac-MS (dBm);
- $L_{Aircraft}$: Attenuation due to the aircraft (dB);
- L_{Prop} : Propagation loss between g-BTS and aircraft (free space path loss model) (dB);
- BL_{ac-MS}: Body loss of ac-MS (dB);
- G_{g-BTS} : Antenna gain of the ground base station (dBi).

With resulting margin for the uplink

$$M_{gBTS} = S_{g-BTS} - P_{rec\,g-BTS} \tag{4}$$

where:

- S_{g-BTS}: Receiver sensitivity of the ground base station (dB).

Note if the margin is positive, it means that the signal received by the ground base station is below its sensitivity.

4.1.4 Scenario 1: MCL Results

4.1.5 GSM Downlink

Table 5: MCL results for GSM900 (scenario1)

GSM900: frequency used 942.5 MHz					
Aircraft height above ground (m)	**Worst case elevation angle (deg)**	**Distance ac-MS/ground BS (km)**	**Path loss (dB)**	**Received power by ac-MS (dBm/channel)**	**Margin (dB)**
3000	57	3.58	103.0	-69.7	-32.3
5000	57	5.96	107.4	-74.1	-27.9
10000	57	11.92	113.4	-80.1	-21.9

Table 6: MCL results for GSM1800 (scenario 1)

GSM1800: frequency used 1842.5 MHz					
Aircraft height above ground (m)	**Worst case elevation angle (deg)**	**Distance ac-MS/ground BS (km)**	**Path loss (dB)**	**Received power by ac-MS (dBm/channel)**	**Margin (dB)**
3000	37	4.96	111.6	-77.6	-24.4
5000	37	8.3	116.1	-82.0	-20.0
10000	37	16.59	122.1	-88.1	-13.9

4.1.6 UMTS Downlink

Table 7: MCL results for UMTS900 (scenario 1)

UMTS900: frequency used 942.5 MHz					
Aircraft height above ground (m)	**Worst case elevation angle (deg)**	**Distance ac-MS/ground BS (km)**	**Path loss (dB)**	**Received power by ac-MS (dBm/channel)**	**Margin (dB)**
3000	57	3.58	103.0	-82.7	-31.3
5000	57	5.96	107.4	-87.1	-26.9
10000	57	11.92	113.4	-93.1	-20.9

Table 8: MCL results for UMTS 2100 (scenario 1)

UMTS2100: frequency used 2140 MHz					
Aircraft height above ground (m)	**Worst case elevation angle (deg)**	**Distance ac-MS/ground BS (km)**	**Path loss (dB)**	**Received power by ac-MS (dBm/channel)**	**Margin (dB)**
3000	37	4.96	112.9	-91.9	-25.1
5000	37	8.30	117.4	-96.3	-20.7
10000	37	16.59	123.4	-102.4	-14.6

4.1.7 LTE Downlink

Table 9: MCL results for LTE450 (scenario1)

LTE450: frequency used: 465 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ac-MS (dBm/channel)	Margin (dB)
3000	57	3.58	96.8	-63.5	-27.0
5000	57	5.96	101.3	-68.0	-22.5
10000	57	11.92	107.3	-74.0	-16.5

Table 10: MCL results for LTE700 (scenario 1)

LTE700: frequency used 773 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ac-MS (dBm/channel)	Margin (dB)
3000	57	3.58	101.2	-67.9	-27.6
5000	57	5.96	105.7	-72.4	-23.1
10000	57	11.92	111.7	-78.4	-17.1

Table 11: MCL results for LTE800 (scenario 1)

LTE800: frequency used 806 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ac-MS (dBm/channel)	Margin (dB)
3000	57	3.58	101.6	-68.3	-25.7
5000	57	5.96	106.0	-72.7	-21.3
10000	57	11.92	112.1	-78.8	-15.2

Table 12: MCL results for LTE900 (scenario 1)

LTE900: frequency used 942.5 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ac-MS (dBm/channel)	Margin (dB)
3000	57	3.58	103.0	-69.7	-27.3
5000	57	5.96	107.4	-74.1	-22.9
10000	57	11.92	113.4	-80.1	-16.9

Table 13: MCL results for LTE1800 (scenario 1)

LTE1800: frequency used 1842.5 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ac-MS (dBm/channel)	Margin (dB)
3000	37	4.96	111.6	-77.6	-16.4
5000	37	8.3	116.1	-82.0	-12.0
10000	37	16.59	122.1	-88.1	-5.9

Table 14: MCL results for LTE2100 (scenario 1)

LTE2100: frequency used 2140 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ac-MS (dBm/channel)	Margin (dB)
3000	37	4.96	112.9	-78.9	-18.1
5000	37	8.3	117.4	-83.3	-13.7
10000	37	16.59	123.4	-89.4	-7.6

Table 15: MCL results for LTE2300 (scenario 1)

LTE2300: frequency used 2350 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ac-MS (dBm/channel)	Margin (dB)
3000	37	4.96	113.7	-79.7	-17.3
5000	37	8.3	118.2	-84.2	-12.8
10000	37	16.59	124.2	-90.2	-6.8

Table 16: MCL results for LTE2600 (scenario 1)

LTE2600-TDD: frequency used 2595 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ac-MS (dBm/channel)	Margin (dB)
3000	37	4.96	114.6	-80.6	-16.4
5000	37	8.3	119.1	-85.0	-12.0
10000	37	16.59	125.1	-91.0	-6.0

Table 17: MCL results for LTE2600 FDD (scenario 1)

LTE2600-FDD: frequency used 2655 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ac-MS (dBm/channel)	Margin (dB)
3000	37	4.96	114.8	-80.8	-14.2
5000	37	8.3	119.3	-85.2	-9.8
10000	37	16.59	125.3	-91.2	-3.8

Table 18: MCL results for LTE3500 (scenario 1)

LTE3500: frequency used 3500 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ac-MS (dBm/channel)	Margin (dB)
3000	37	4.96	117.2	-83.2	-12.8
5000	37	8.3	121.7	-87.6	-8.4
10000	37	16.59	127.7	-93.6	-2.4

Table 19: MCL results for LTE3700 (scenario 1)

LTE3700: frequency used 3750 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ac-MS (dBm/channel)	Margin (dB)
3000	37	4.96	117.8	-83.7	-12.3
5000	37	8.3	122.3	-88.2	-7.8
10000	37	16.59	128.3	-94.2	-1.8

4.1.8 Scenario 2: MCL Results

4.1.9 GSM Uplink

Table 20: MCL results for GSM900 (scenario 2)

GSM900: frequency used 897.5 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ground BS (dBm/channel)	Margin (dB)
3000	57	3.58	102.5	-79.2	-24.8
5000	57	5.96	107.0	-83.7	-20.3
10000	57	11.92	113.0	-89.7	-14.3

Table 21: MCL results for GSM1800 (scenario 2)

GSM1800: frequency used 1747.5 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ground BS (dBm/channel)	Margin (dB)
3000	37	4.96	111.2	-87.1	-16.9
5000	37	8.3	115.6	-91.6	-12.4
10000	37	16.59	121.6	-97.6	-6.4

4.1.10 UMTS Uplink

Table 22: MCL results for UMTS900 (scenario 2)

UMTS900: frequency used 897.5 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ground BS (dBm/channel)	Margin (dB)
3000	57	3.58	102.5	-91.2	-29.8
5000	57	5.96	107.0	-95.7	-25.3
10000	57	11.92	113.0	-101.7	-19.3

Table 23: MCL results for UMTS2100 (scenario 2)

UMTS2100: frequency used 1950 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ground BS (dBm/channel)	Margin (dB)
3000	37	4.96	112.1	-100.1	-20.9
5000	37	8.3	116.6	-104.5	-16.5
10000	37	16.59	122.6	-110.6	-10.4

4.1.11 LTE Uplink

Table 24: MCL results for LTE450 (scenario 2)

LTE450: frequency used 455 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ground BS (dBm/channel)	Margin (dB)
3000	57	3.58	96.6	-86.3	-15.2
5000	57	5.96	101.1	-90.8	-10.7
10000	57	11.92	107.1	-96.8	-4.7

Table 25: MCL results for LTE700 (scenario 2)

LTE700: frequency used 718 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ground BS (dBm/channel)	Margin (dB)
3000	57	3.58	100.6	-90.3	-11.2
5000	57	5.96	105.0	-94.7	-6.8
10000	57	11.92	111.0	-100.8	-0.7

Table 26: MCL results for LTE800 (scenario 2)

LTE800: frequency used 847 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ground BS (dBm/channel)	Margin (dB)
3000	57	3.58	102.0	-91.7	-9.8
5000	57	5.96	106.5	-96.2	-5.3
10000	57	11.92	112.5	-102.2	0.7

Table 27: MCL results for LTE900 (scenario 2)

LTE900: frequency used 897.5 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ground BS (dBm/channel)	Margin (dB)
3000	57	3.58	102.5	-92.2	-9.3
5000	57	5.96	107.0	-96.7	-4.8
10000	57	11.92	113.0	-102.7	1.2

Table 28: MCL results for LTE1800 (scenario 2)

LTE1800: frequency used 1747.5 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ground BS (dBm/channel)	Margin (dB)
3000	37	4.96	111.2	-100.1	-1.4
5000	37	8.3	115.6	-104.6	3.1
10000	37	16.59	121.6	-110.6	9.1

Table 29: MCL results for LTE2100 (scenario 2)

LTE2100: frequency used 1950 MHz					
Aircraft height above ground (m)	Worst case elevation angle (deg)	Distance ac-MS/ground BS (km)	Path loss (dB)	Received power by ground BS (dBm/channel)	Margin (dB)
3000	37	4.96	112.1	-101.1	-0.4
5000	37	8.3	116.6	-105.5	4.0
10000	37	16.59	122.6	-111.6	10.1

Table 30: MCL results for LTE2300 (scenario 2)

LTE2300: frequency used 2350 MHz					
Aircraft height above ground (m)	**Worst case elevation angle (deg)**	**Distance ac-MS/ground BS (km)**	**Path loss (dB)**	**Received power by ground BS (dBm/channel)**	**Margin (dB)**
3000	37	4.96	113.7	-102.7	1.2
5000	37	8.3	118.2	-107.2	5.7
10000	37	16.59	124.2	-113.2	11.7

Table 31: MCL results for LTE2600 TDD (scenario 2)

LTE2600-TDD: frequency used 2595 MHz					
Aircraft height above ground (m)	**Worst case elevation angle (deg)**	**Distance ac-MS/ground BS (km)**	**Path loss (dB)**	**Received power by ground BS (dBm/channel)**	**Margin (dB)**
3000	37	4.96	114.6	-103.6	2.1
5000	37	8.3	119.1	-108.0	6.5
10000	37	16.59	125.1	-114.0	12.5

Table 32: MCL results for LTE2600 FDD (scenario 2)

LTE2600-FDD:frequency used 2535 MHz					
Aircraft height above ground (m)	**Worst case elevation angle (deg)**	**Distance ac-MS/ground BS (km)**	**Path loss (dB)**	**Received power by ground BS (dBm/channel)**	**Margin (dB)**
3000	37	4.96	114.4	-103.3	1.8
5000	37	8.3	118.9	-107.8	6.3
10000	37	16.59	124.9	-113.8	12.3

Table 33: MCL results for LTE3500 (scenario 2)

LTE3500: frequency used 3500 MHz					
Aircraft height above ground (m)	**Worst case elevation angle (deg)**	**Distance ac-MS/ground BS (km)**	**Path loss (dB)**	**Received power by ground BS (dBm/channel)**	**Margin (dB)**
3000	37	4.96	117.2	-106.1	4.6
5000	37	8.3	121.7	-110.6	9.1
10000	37	16.59	127.7	-116.6	15.1

Table 34: MCL results for LTE3700 (scenario 2)

LTE3700: frequency used 3750 MHz					
	Worst case elevation angle (deg)	**Distance ac-MS/ground BS (km)**	**Path loss (dB)**	**Received power by ground BS (dBm/channel)**	**Margin (dB)**
3000	37	4.96	117.8	-106.7	5.2
5000	37	8.3	122.3	-111.2	9.7
10000	37	16.59	128.3	-117.2	15.7

4.1.12 MCL Summary

The Scenario 1 (downlink: g-BTS transmit, ac-MS receive) analysis shows that whatever the cellular technolgies and the operating frequency bands, the ground base station is always visible by the airborne User Equipment.

The Scenario 2 (uplink: g-BTS receive, ac-MS transmit) analysis shows that the ground base station could not receive the signal from an airborne User Equipment based on LTE and whose operation is above 2100 MHz. For 1800 MHz and 2100 MHz, the Airborne User equipment will not be visible by the ground base station above 4000 metres.

4.2 MONTE CARLO ANALYSIS

4.2.1 SEAMCAT Modelling

Using the key alignment as determined in the above section, interference scenarios have been developed in the SEAMCAT tool for a number of frequency bands and cellular technologies to examine the impact of interference aggregation from other base stations that are also visible to the airborne user terminal that is communicating with a terrestrial base station.

Figure 2 illustrates the geometry used in the interference scenarios.

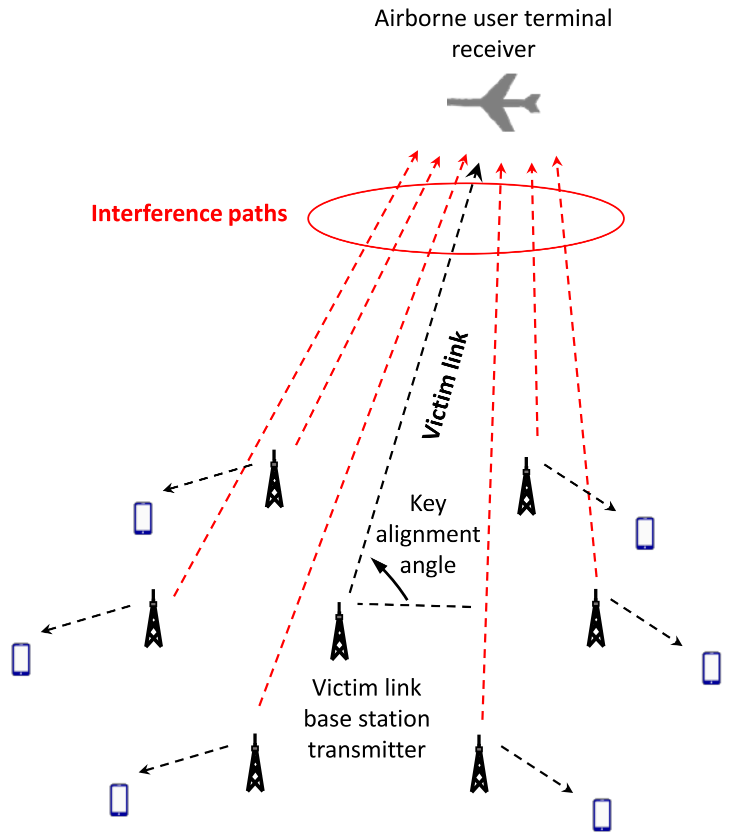

Figure 2: SEAMCAT analysis geometry

The following approach has been adopted in developing the SEAMCAT interference models:

- The model aims to analyse the impact of interference aggregation from a number of terrestrial base station transmitters into an airborne user terminal receiver assumed to be communicating with a terrestrial base station transmitter;
- The victim link is assumed to be operating at the key alignment angle which is calculated to be 57 degrees for scenarios < 1 GHz and 37 degrees for scenarios > 1 GHz from the results of the received power calculations implemented in the first modelling step;
- The interfering terrestrial base station transmitters are located at a defined distance and an azimuth angle with respect to the victim link terrestrial base station transmitter;
- Interference power calculated at the airborne user terminal receiver is aggregated from a number of tiers of base station transmitters as shown in Figure 3;

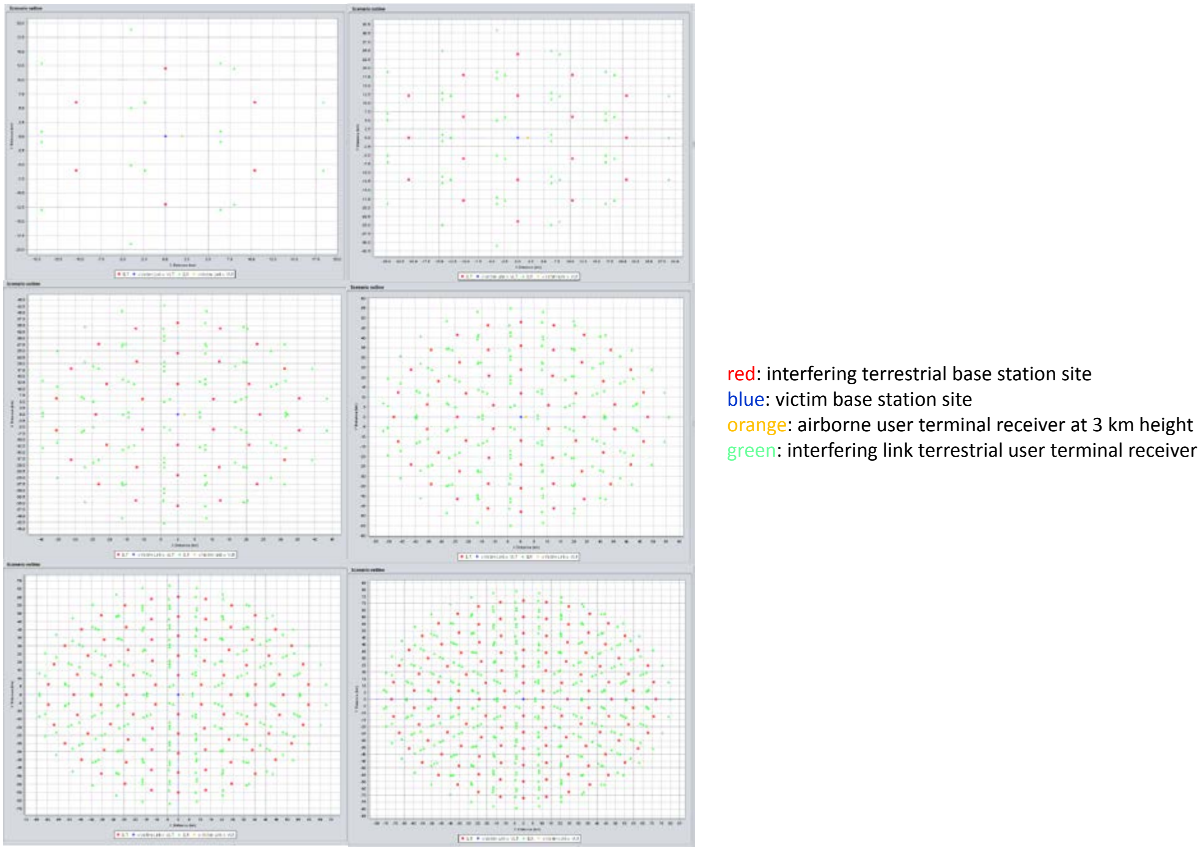

Figure 3: Example set of SEAMCAT interference modelling scenarios for UMTS 900 with 1 – 6 tiers of interferers

- The distance between the interfering base station transmitters and the victim link base station transmitter is determined by the frequency re-use factor. For the UMTS and LTE technologies, the re-use factor is 1 and the distance corresponds to the inter-site distance as shown in Figure 4;

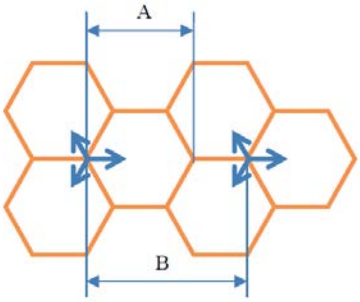

Figure 4: Inter-site distance (A: cell radius, B: inter-site distance)
(Source: Report ITU-R M.2292 [13])

- In the case of GSM, a 7-cell re-use pattern (with a cell area equal to the area covered by three sectors shown in Figure 4) is assumed and the inter-site distance for co-frequency operation is calculated from B = A x √3N where N is 7;
- The interference models are static as the relative positions of interfering transmitters and the victim receiver is fixed based on the calculated key alignment angle where the received power in the victim link is maximum;
- The victim link received power, the aggregate interference power and the airborne user terminal receiver noise floor are combined to calculate the C/(N+I) ratio at the airborne user terminal receiver. The power calculations assume free space path loss and take account of relative antenna gains at the base station transmitters. Furthermore, three levels of aircraft attenuation (i.e. 5) are assumed for both the victim link and interference paths;
- The calculated C/(N+I) is compared against the threshold C/(N+I) level to determine if the victim link is sustainable.

4.2.2 SEAMCAT Analysis Results

The detailed results of the analysis obtained from the SEAMCAT interference models are presented in ANNEX 3: for different frequency bands and cellular technologies. The following table provides a summary of the results where, for each scenario, the impact of aggregate interference in the victim link from surrounding interfering base stations is assessed by specifying whether the victim link is sustainable (i.e. the victim link C/(N+I) threshold is satisfied) or unsustainable (i.e. the victim link C/(N+I) threshold is not satisfied).

The interference analysis has considered GSM, UMTS and LTE technologies and their relevant operating frequency bands ranging from 450 MHz to 2100 MHz. In the case of UMTS where the impact assessment is based on the ability to detect the pilot channels used to be able to register to the ground network, the implications of interfering base station traffic loading have been taken into account by varying the transmit power to account for 50% and 75% loading. Therefore, two sets of scenario have been considered for UMTS. In the first set, it is assumed that the interfering base stations are 50% loaded and they operate at the power level of 36 dBm / 3.84 MHz (i.e. 3 dB above the power level representing 0% loading). This power level is then increased by further 3 dB to represent 75% loaded interfering base stations (i.e. 39 dBm / 3.84 MHz).

✓ :The victim link is sustainable
✗ : The victim link is not sustainable

Table 35: Interference Analysis Summary

Technology	Aircraft Height (km)	3	5	10
	Aircraft Loss (dB)	5	5	5
GSM 900	1 tier	×	×	×
	2 tiers	×	×	×
	3 tiers	×	×	×
GSM 1800	1 tier	×	×	×
	2 tiers	×	×	×
	3 tiers	×	×	×
UMTS 900 (50% loaded)	1 tier	✓	✓	✓
	2 tiers	✓	✓	✓
	3 tiers	✓	✓	✓
	4 tier	✓	✓	✓
	5 tiers	✓	✓	×
	6 tiers	✓	×	×
UMTS 900 (75% loaded)	1 tier	✓	✓	✓
	2 tiers	✓	✓	✓
	3 tiers	✓	✓	×
	4 tier	✓	×	×
UMTS 2100 (50% loaded)	1 tier	✓	✓	✓
	2 tiers	✓	✓	✓
	3 tiers	✓	✓	×
	4 tier	✓	×	×
	5 tiers	✓	×	×
	6 tiers	×	×	×
UMTS 2100 (75% loaded)	1 tier	✓	✓	✓
	2 tiers	✓	×	×
	3 tiers	×	×	×
LTE 450	1 tier	✓	×	×
	2 tiers	×	×	×
	3 tiers	×	×	×
LTE 800	1 tier	✓	×	×
	2 tiers	×	×	×
	3 tiers	×	×	×
LTE 1800	1 tier	×	×	×
	2 tiers	×	×	×
	3 tiers	×	×	×

4.3 OTHER MODELLING ANALYSIS

In this section the results of comprehensive SINR modelling using MATLAB are presented. Results are provided for assumptions of 2, 3 and 4 tiers of interferers. However, where a particular number of tiers causes the maximum SINR to fall below the minimum acceptable for the specific technology considered, plots and results are not produced for additional number(s) of tiers.

Table 36 provides the parameters which are used for GSM, UMTS, and LTE models.

Table 36: Parameters for All Models

Parameter	Value
Base station antenna beamwidth	65°
Base station antenna down tilt	3°
Base station feeder loss	0 dB
Aircraft attenuation	5 dB
Body loss	4 dB
Mobile antenna gain	-3 dB
Antenna model	Average side lobe: improved

4.3.1 GSM Results

Table 37 provides the GSM parameters used in the analysis for the bands 900 MHz and 1800 MHz.

Table 37: Parameters for GSM

Parameter	Value
Re-use cluster size	7
No interfering sectors	1
Base station transmit power	43 dBm
Signal bandwidth	0.20 MHz
Mobile noise figure	7 dB
C/(N+I)	9 dB

Table 38 provides the GSM maximum C/I results for the bands 900 MHz and 1800 MHz.

Table 38: GSM Summary Results

Conditions	Maximum C/I (dB)
GSM900, 3 km Altitude, 2 tiers	-0.1
GSM900, 6 km Altitude, 2 tiers	-3.0
GSM900, 10 km Altitude, 2 tiers	-3.7
GSM1800, 3 km Altitude, 2 tiers	0.1
GSM1800, 6 km Altitude, 2 tiers	-1.8
GSM1800, 10 km Altitude, 2 tiers	-5.0

4.3.2 GSM Conclusion

The C/(N+I) analysis generally concludes that no successful registration of user equipment onboard the aircraft is possible in any of the GSM frequency bands considered. Further discussion of the results is provided in Section 5.2.

4.3.3 UMTS Results

Table 39 provides the UMTS parameters for the bands 900 MHz and 2100 MHz needed for the analysis.

Table 39: Parameters for UMTS

Parameter	Value
Re-use cluster size	1
No interfering sectors	3
Base station transmit power	33 dBm
Signal bandwidth	3.84 MHz
Mobile noise figure	9.0 dB
C/(N+I)	-20 dB

Table 40 provides the UMTS maximum C/I results for the bands 900 MHz and 2100 MHz.

Table 40: UMTS Summary Results

UMTS Band (MHz)	Altitude (km)	Loading	# Tiers	Maximum C/I (dB)
900	3	50%	2	-11.3
900	3	50%	3	-13.6
900	3	50%	4	-15.1
900	6	50%	2	-12.2
900	6	50%	3	-14.7
900	6	50%	4	-16.7
900	10	50%	2	-14.5
900	10	50%	3	-16.1
900	10	50%	4	-17.5
900	3	75%	2	-14.3
900	3	75%	3	-16.6
900	3	75%	4	-18.1
900	6	75%	2	-15.2
900	6	75%	3	-17.7
900	6	75%	4	-19.7
900	10	75%	2	-17.5
900	10	75%	3	-19.1
900	10	75%	4	-20.4
2100	3	50%	2	-14.1
2100	3	50%	3	-15.5
2100	3	50%	4	-16.4
2100	6	50%	2	-17.0
2100	6	50%	3	-18.8
2100	6	50%	4	-20.0
2100	10	50%	2	-18.1
2100	10	50%	3	-20.5
2100	3	75%	2	-17.1
2100	3	75%	3	-18.5
2100	3	75%	4	-19.4
2100	6	75%	2	-20.0

4.3.4 UMTS Conclusions

The C/(N+I) analysis generally concludes that successful registration of user equipment onboard the aircraft is possible in any of the UMTS frequency bands considered.

For higher altitudes, and depending on the load factor, the analysis shows that the maximum C/I is at the limit of the C/I threshold. The received C/I by onboard user equipment will vary due to the fast moving aircraft. In addition, it should be noted that the altitude of the aircraft will be certainly at least at 10 km or higher during the cruise flight

Further discussion of the results is provided in Section 5.2.

4.3.5 LTE Results

Table 41 provides the LTE parameters used in the analysis for the bands 450 MHz, 700 MHz, 800 MHz, 900 MHz, and 2100 MHz.

Table 41: Parameters for LTE

Parameter	Value
Re-use cluster size	1
No interfering sectors	3
Base station transmit power	46 dBm
Signal bandwidth	9.00 MHz
Mobile noise figure	9.0 dB
C(/I+N)	-6dB

Table 42 provides the maximum C/I results for LTE in bands 450 MHz, 700 MHz, 800 MHz, 900 MHz, 1800 MHz and 2100 MHz.

Table 42: LTE Summary Results

LTE Band (MHz)	Altitude (km)	Loading	# Tiers	Maximum C/I (dB)
450	3	50%	2	-5.3
450	3	50%	3	-7.6
450	6	50%	2	-6.2
450	10	50%	2	-8.5
450	3	100%	2	-8.3
450	6	100%	2	-9.2
450	10	100%	2	-11.5
700	3	50%	2	-5.3
700	3	50%	3	-7.6
700	6	50%	2	-6.2
700	10	50%	2	-8.5
700	3	100%	2	-8.3
700	6	100%	2	-9.2
700	10	100%	2	-11.5
800	3	50%	2	-5.3
800	3	50%	3	-7.6
800	6	50%	2	-6.2
800	10	50%	2	-8.5
800	3	100%	2	-8.3
800	6	100%	2	-9.2
800	10	100%	2	-11.5
900	3	50%	2	-5.3
900	3	50%	3	-7.6
900	6	50%	2	-6.2
900	10	50%	2	-8.5
900	3	100%	2	-8.3
900	6	100%	2	-9.2
900	10	100%	2	-11.5
1800	3	50%	2	-6.9
1800	6	50%	2	-10.2
1800	10	50%	2	-11.6
1800	3	100%	2	-9.9
1800	6	100%	2	-13.2
1800	10	100%	2	-14.6
2100	3	50%	2	-8.1
2100	6	50%	2	-10.9
2100	10	50%	2	-12.0
2100	3	100%	2	-11.1
2100	6	100%	2	-13.9
2100	10	100%	2	-14.9

4.3.6 LTE Conclusions

The C/(N+I) analysis generally concludes that no successful registration of user equipment onboard the aircraft is possible in any of the LTE frequency bands considered.

Further discussion of the results is provided in Section 5.2.

4.4 PRACTICAL SCENARIO - METHODOLOGY FOR THE CONNECTIVITY ANALYSIS

4.4.1 Criterion for the evaluation of the connectivity to the ground mobile network

In general, when the user equipment is switched on, it initially registers to the last Public Land Mobile Network (PLMN) or a higher priority PLMN if available. If the last PLMN or a higher priority PLMN are not available the user equipment will scan all the frequency bands to check whether any are available from a non-forbidden operator prior to any attempt to connect. For any technology (GSM, UMTS, LTE), the connection of a user equipment to a mobile cellular network requires preliminary procedures such as decoding of synchronisation channels or (physical) broadcast channels, to access parameters essential for initial access of the cell (such as downlink system bandwidth, the Physical Hybrid ARQ Indicator Channel structure), which are located in the Master Information Block (MIB). These procedures can be summarised in the following phases:

- **Phase 1:** the user equipment is only receiving (downlink signals or channels) without transmitting. Note that at some point in phase 1, the user equipment will perform measurements in the (cell-specific) (RSRP/RSRQ for LTE, for UMTS, for GSM). The following three steps cover this phase:
  1. correctly decode the synchronisation signals (for LTE: PSS/SSS);
  2. decode the PBCH (read the MIB);
  3. read the System Information (since it's sent on the PDSCH, the user equipment needs to be able to correctly decode the PCFICH, the PDCCH and the PDSCH).

  At the end of phase 1, the user equipment is camped on the cell.
- **Phase 2:** The user equipment will start transmitting with a PRACH request, which is always the first step for the establishment of an RRC connection.
- **Phase 3:** Activate connections with that given cell; if user equipment fails to connect with the cell, the user equipment cannot attach to the network.
- In order to cover steps 1 and 2 from the phase 1, the following two categories of threshold are triggered to output whether connection attempt may be performed or not:
  - receiver sensitivity;
  - QoS ratio.

During the network planning and optimisation, the coverage area is predicted using the terrain profile and the receiver sensitivity, however, this alone is not sufficient. For a ground mobile network, it is also important to take into account the impact of other surrounding ground base stations in order to reduce the interference of the adjacent cells. In addition, the user equipment normally receives signals at different power levels from multiple base stations, particularly at the cell edge, all transmitting in the same channel for UMTS and LTE or in the adjacent channel for GSM. Thus, inside well "theoretical" covered areas, the "unwanted" signals behave as an interference part, preventing a proper decoding of the DL synchronisation signals. Hence the Signal Quality is the second criterion which is more appropriate to account interferences from neighbouring cell BSs than the receiver sensitivity and to determine whether a connection can be initiated. This parameter is expressed in terms of:

  - E_c/I_o [3] for UMTS where E_c depicts received energy per chip of the pilot channel divided by the total noise + interference power density $I_{o;}$
  - E_s/I_{ot} [4] for LTE where E_s depicts received symbol energy per Resource Element (RE) and I_{ot} depicts the received power spectral density of the total noise and interference for a certain RE;
  - C/I_c [5] for GSM.

[3] 3GPP TS 25.133 [19] Section 3.2
[4] 3GPP TS 36.133 [20] Section 3.2

The characteristic of the Signal Quality parameter is that when the noise *N* is negligible towards interference *I*, any parameter affecting in the way as *I* and *C* makes QoS ratio unchanged. Thus, SINR values[6] remain almost unchanged within the radius of the analysis area for any attenuation due to the aircraft fuselage and user equipment antenna gain (both affecting *C* and *I*).

4.4.2 Calculation of the aggregated effect of BSs

In the case where ground BSs in adjacent cells (of a cell *A*) may cause interference to other UEs located at the cell edge, UEs onboard the aircraft would be subject to a higher levels of interference owing to the higher number of BSs the UEs have visibility of through the aircraft windows. To determine the level of the aggregate interference this analysis accounts for BSs that are in line-of-sight (LOS) of the aircraft. This assumption implies that in addition of the horizon distance condition[7], the relief of the terrain must be also accounted to assess the LOS/non-LOS status of the BSs with respect to the aircraft. The highest-resolution topographic data generated from NASA's Shuttle Radar Topography Mission (SRTM) [21] was applied within the French territory, with 1 arc-second sample accuracy (or about 30 metres)[8]. Note that the approach of only considering BSs in LOS of the aircraft is conservative since BSs that are non-LOS could (slightly) influence C/(N+I) if loss due to diffraction (after LOS) is not significant[9] with respect to the interference component they would bring the aggregated interference effect.
In order to reflect the diversity of profiles[10] (hill, plain, mountain), the following different flight routes were selected (as shown in Figure 5).

- Paris-Nice (surrounding Alps mountains chain ≥ 3000 m);
- Paris-Toulouse (Pyrénées & Plateau de Mille-Vaches mountains chain 500 m ≤ h ≤ 2000 m);
- Paris-Brest (plains);
- Paris-Strasbourg (The Vosges mountains chain 500 m ≤ h≤ 2000 m).

[5] 3GPP TS 45.005 [14] Section 6.3.1
[6] If N<<I, then C/(N+I)~C/I so that $L_f G_{UE} C/(L_f G_{UE} I)=C/I$.
[7] i.e. distance(BS,Aircraft) ≤ $d_{horizon}$(BS,Aircraft)
[8] SRTM data files are available in the following link: http://dds.cr.usgs.gov/srtm/
[9] for the case BSs/distance(BS,Aircraft)>$d_{horizon}$(BS,Aircraft),but distance(BS,Aircraft)≈$d_{horizon}$(BS,Aircraft)
[10] Since it may affect the altitude of the aircraft in the flight plan.

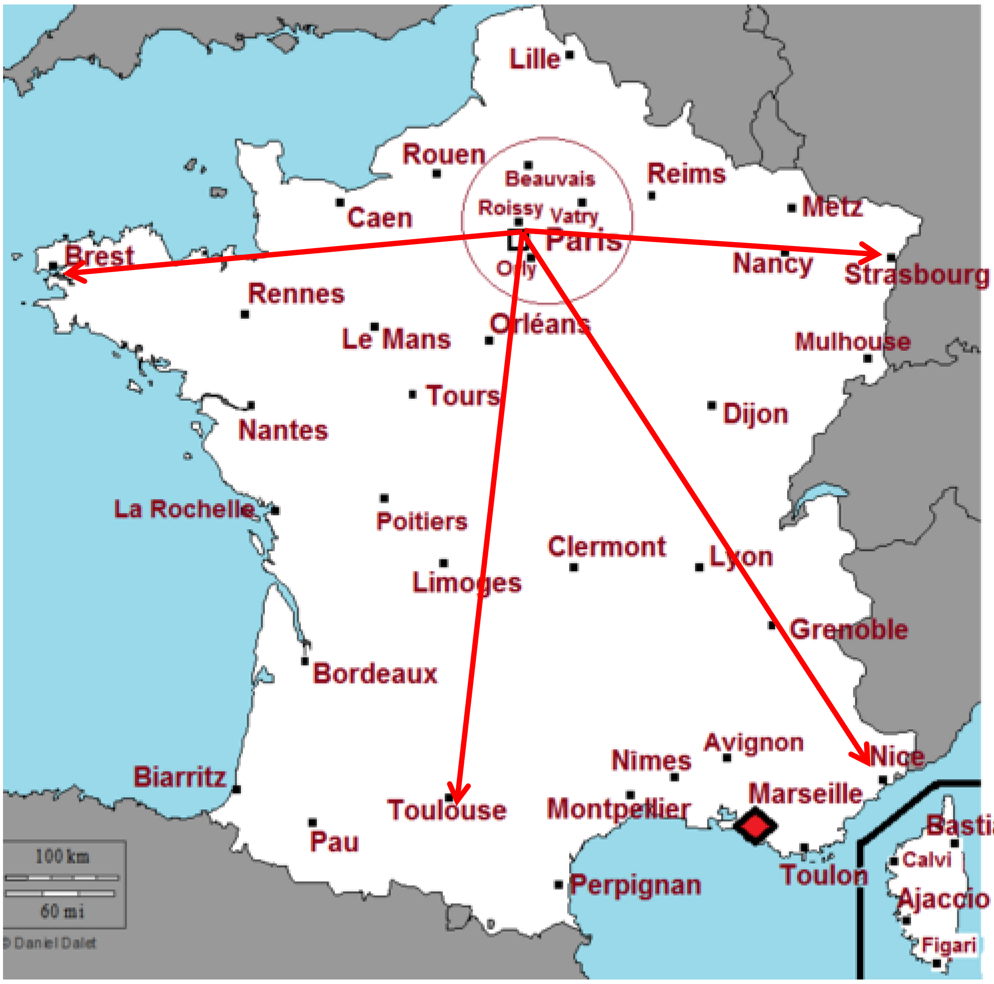

Figure 5: Flight routes considered to reflect the diversity of relief

4.4.3 Propagation model used between ground BS and Aircraft

The location of the transmitter (ground-based BS) and receiver (onboard UE) led to the following propagation models (which differ beyond the horizon distance denoted $d_{horizon}$) being considered:

- ITU-R Recommendation P.525 [11] does not account non-LOS issues.
- ITU-R Recommendation P.528 [10] is valid for both LOS and non-LOS cases:
  - It coincides with ITU-R Recommendation P.525 for the LOS case, reached for distance<$d_{horizon}$.
  - It includes additional losses for NLOS, such as diffraction, ducting effects and a time percentage that encompasses several atmospheric phenomena.

As all BSs considered in the SINR calculation within LOS with of the aircraft, d(BS,aircraft) ≤ $d_{horizon}$, both propagation models match and Free Space Loss could be assumed in the received SINR calculation.

4.4.4 Results

The analysis estimates the margin between the received SINR at ac-MS (at the real altitude of the aircraft) and $SINR_{Threshold}$ for different LTE frequency bands denoted as:

$$\Delta^{*} = max\left(SINR_{i,j,k} - SINR_{Threshold}\right) = max_{i,j,k}\left(\Delta_{i,j,k}\right)$$

where:

- i refers to the operator index i (up to 4 depending on the frequency ranges);
- j is the jth corridor path j=1..4;

- k corresponds to the kth point of the corridor path, k=1..100;
- Δ*≥0 corresponds to the case where ac-MS can decode the DL synchronisation signal;
- Δ*≤0 expresses a failure in the synchronisation signal decoding.

When Δ*≥0, the ac-MS receives synchronisation signals but it does not imply the ac-MS receives it during the whole flight, for all routes and any operator. Figure 6 illustrate this for different flight routes (Paris to Nice and Paris to Brest) at different altitudes (6000 m[11] and 3000 m respectively), when measuring DL SINR for 900MHz UMTS. The abscissa refers to the sampling of the path taken by the aircraft into points corridor (e.g. *N* points set means that the path is split into N-1 segments) while the ordinate depicts the received SINR at ac-MS. It can be seen that only 2 (contiguous) points for Paris-Nice depicted in blue circle (left side figure) enables the decoding of the synchronisation signal (i.e. equivalent to 36sx2=1mn12s) while it is more than half of the flight time for Paris-Brest labelled in red circle (right side figure).

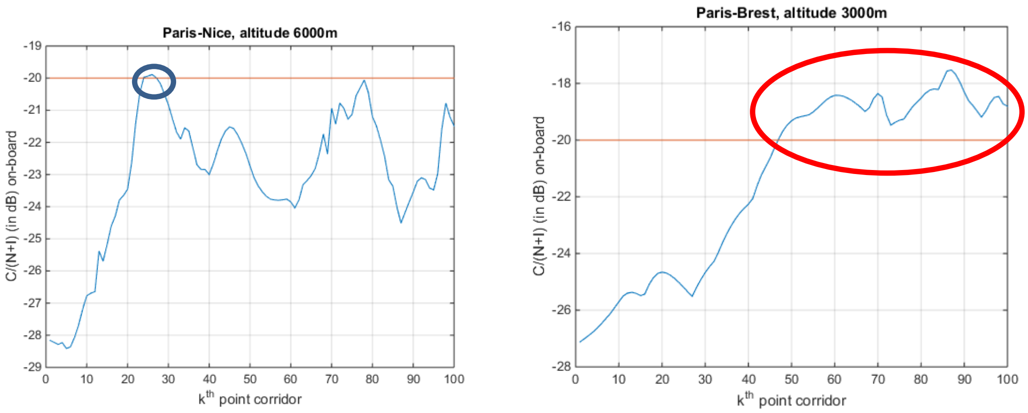

Figure 6: UMTS900 downlink SINR measurement for Paris to Nice and Paris to Brest routes at different altitudes

In addition, due to the landing and take-off phases, the aircraft does not have a constant altitude during the whole flight, therefore, it is more relevant to compute the SINR at ac-MS based on the real altitude. One source website[12] provides access to information related to the flight, providing altitude and speed of the aircraft. As an example, Figure 7 investigates the received SINR (for UMTS900) by considering two different flight routes (Paris to Nice and Paris to Brest) and applying the real altitude of the aircraft during the flight. It should be noted that in accordance with the current MCA regulatory framework, this analysis examines the potential for connectivity of ac-MSs above 3000 m with respect to the ground network. This explains why SINR results are not provided in Figure 7 for altitudes lower than 3000 m during landing and take-off procedures, corresponding to the first and the last points of the corridor.

[11] Theoretically, this flight corridor cannot be performed for altitude lower than 5000m since it surrounds the Alps whose top is Mont-Blanc (4807 m) and since air corridor does not change during the flight (except for safety/security reasons). ANNEX 5: shows for different paths that the typical altitude selected by aircraft for this route is equal to or higher than 6000m.

[12] http://www.flightradar24.com/

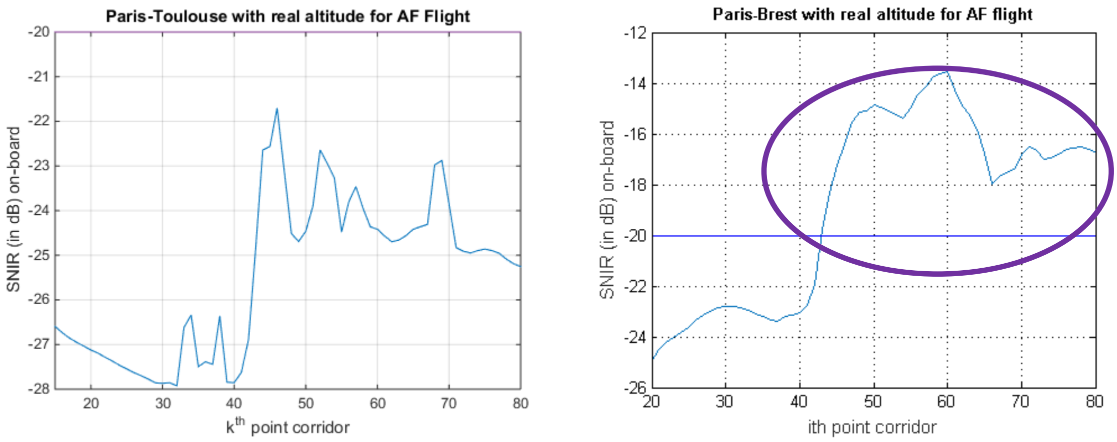

Figure 7: Received SINR for UMTS900 by considering Paris to Nice and Paris to Brest routes

The SINR curve shows that the DL synchronisation signal would be decoded by the ac-MS only for Paris-Brest flight during more than half of the path (labelled with purple circle in the right hand side of the figure). Note that the results are consistent regardless of flight direction (Paris->Nice, Nice->Paris) and airline (Air France, EasyJet).

Table 43 shows Δ* for different technologies and frequency ranges at the real altitude of the aircraft for the Paris – Toulouse flight path using the digital terrain model:

Table 43: Δ* for GSM 900, LTE800, LTE1800, UMTS 2100 and LTE2600 at the real altitude of the aircraft (Paris – Toulouse)

Scenarios	800MHz LTE	1800MHz LTE	2600MHz LTE	900MHz GSM	2100MHz UMTS
$Max_{i,j,k}(SINR_{i,j,k})$	-12.8dB	-17.1dB	-12.4dB	-2.5dB	-8.2dB
$SINR_{Threshold}$	-6dB	-6dB	-6dB	9dB	-20dB
Δ*	-6.8dB	-11.1dB	-6.4dB	-11.5dB	11.8dB

The results for 2600 MHz and 800 MHz are consistent with each other, but are different from those for 1800 MHz. This variation can be explained by the greater number of base station deployments recorded in the French database of macro assignments at 1800 MHz when compared with the numbers for 800 MHz and 2600 MHz. Therefore, the aggregated effect of the interference is much greater for 1800 MHz than for the other frequencies.

These results can thus be considered as conservative given that:

- $Max_{i,j,k}(SINR_{i,j,k})$ is the max received SINR obtained among all operators, path, point of the path for a given frequency band. As an example, Figure 8 depicts the situation where $SINR_{real}$ is reached.
- LTE deployment is on-going within the French territory for 800MHz, 1800MHz and 2600MHz. It is then expected that the amount of BSs will increase, leading to an increase in the aggregation effect of the interference. This trend could result in a possible reduction in the SINR received by an ac-MS.

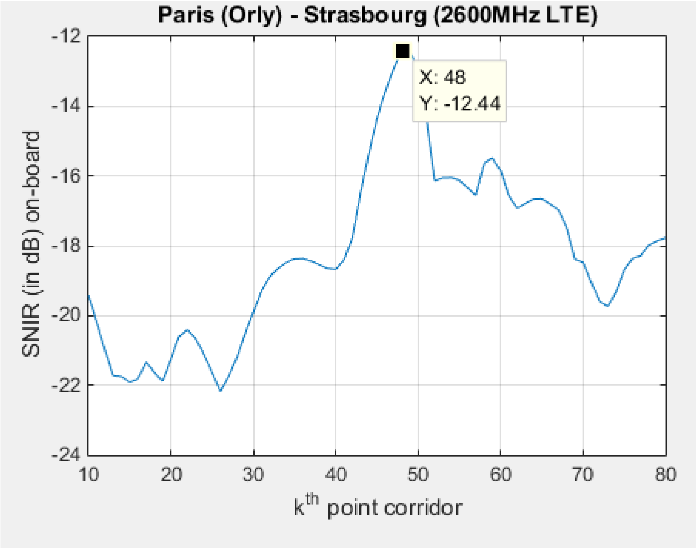

Figure 8: SINR at real altitude

Based on this analysis, it appears that no connectivity for LTE band between ac-MS and ground BS can be obtained since ac-MS can never decode DL PSS or SSS signals for aircraft surrounding the French territory.

4.4.5 Practical scenario conclusion

The results of the analysis assuming real life deployment data and flight path information corroborate those of the other connectivity analysis.

4.5 UPLINK IMPACT ON GROUND BASED UMTS NETWORKS

The connectivity analysis identified that connectivity of ac-MS to ground based UMTS networks is possible where no NCU is employed by the MCA system. The following analysis examines the impact of that connectivity on the performance of ground based UMTS networks.

One way to measure the degradation of the capacity is to consider the throughput loss metric. A similar approach was adopted in CEPT Report 48 [4]. Expressed in terms of spectral efficiency (bps per Hz) in both links, throughput can be related to the signal quality performance (i.e. SINR). The user throughput loss corresponds to the degradation of the signal quality (from *C/N* to *C/(N+I)* where *I* represents inter-cell interference. SINR refers to the signal to noise plus interference ratio. At the cell edge SINR= $C_{min}/(N+I)$, where C_{min} refers to the receiver sensitivity. Since SINR (at BS's receiver) varies within the cell, user throughput also varies within the cell. As a metric for describing the cell performance, throughput loss per cell corresponds to the integration of the throughput loss per user for all possible locations of the user within the cell. User throughput in a given cell is dependent upon the selected application, the location of the UE with respect of the serving BS, and the mobility of the UE. Cell throughput is not constant, and requires the average cell throughput to be considered. Throughput loss per cell is time dependent for specific interference events. It is therefore appropriate in the context of MCA to consider the time averaged cell & network throughput.

4.5.1 Calculation of throughput loss

In UL, all UEs (ground and aircraft based) that connect to the ground network perform transmit power control (TPC) in accordance with the targeted QoS and their location with respect to the BS. TPC controls the signal quality at the BS receiver to establish the required SINR for the target data rate. If the SINR requirement can't be fulfilled for all UEs, Congestion Control (CC) reduces the data rate for the UE or Admission Control (AC) may refuse individual connections. The modelling considered the latter in order to maintain the same data rate.

Mapping SINR to the data rate assumed values described in 3GPP TS 25.104 [16].

- Aircraft subscribers (ac-MS) will be introduced with an AWGN SINR value for 20.7 kbps (FRC7 at 120 km/h with 30% of 69.0) without receiver diversity, as specified in ETSI TS 125 104 [16] section 8.2.1.1.
- Ground subscribers (g-MS) will be modelled with an SINR as specified in ETSI TS 125 104 Table 8.19 and section A.9 according to "pedestrian A" model.

Only transport formats available in the above specification are used as defined in the fixed reference channels (FRC1...FRCn).

As described in Section 4.4.1, SINR is equivalent to E_c/I_o for the UMTS operations. These parameters will be treated as synonymous.

The loss in capacity has been assessed with respect to a reference capacity. That is, a nominal throughput (data rate loaded over a given number of simultaneous users) for a given selected application in absence of an interfering ac-MS. The throughput loss has then been derived over the same area assuming additional ac-MSs giving rise to an increased noise floor, triggering an increase of the e.i.r.p. of g-MSs (due to the operation of the TPC algorithm).

Transmitting ac-MSs that are connected to a (serving) ground cell impact the throughput of these g-MSs in the serving cell. BS from other (non-serving) cells will also receive interference from ac-MS transmissions, possibly resulting in loss of throughput to those g-MSs. This analysis considers the impact of 5 and 30 ac-MSs on the inter-cell interference environment assuming different homogeneous data rates among g-MSs.

The analysis considers the flight path between Paris and Toulouse, based on a UMTS 2100 French network deployment and the digital terrain model. The results of the analysis are provided in Table 44.

Table 44: Throughput loss for UMTS 2100 (Paris-Toulouse)

g-MS data rate Scenario	# g-MSs connected per serving cell without ac-MSs	Average Cell Throughput loss during one flight (# ac-MSs=30)	Average Cell Throughput loss during one flight (# ac-MSs=5)
$D_{g\text{-}MS}$=1349kb/s	1	0.1%	0.01%
$D_{g\text{-}MS}$=1215kb/s	2	39%	39%
$D_{g\text{-}MS}$=947kb/s	2	21.7%	21.7%
$D_{g\text{-}MS}$=578kb/s	4	20.8%	20.8%
$D_{g\text{-}MS}$=355kb/s	5	4.6%	4.6%
$D_{g\text{-}MS}$=152kb/s	12	7.7%	7.6%

4.6 UPLINK IMPACT ON GROUND BASED UMTS NETWORKS – CONCLUSION

The results of the analysis identify that ac-MS transmissions negatively impact the performance of ground based UMTS networks. The extent of the degradation described in Table 44 is particular to the assumptions used in the analysis. Actual degradation will vary according to interference environments (For example, network response, traffic model and distribution, UE deployments, terrain, etc.).

5 CONCLUSIONS

5.1 MCL ANALYSIS

The MCL analysis shows that visibility of both uplink and downlink transmissions is possible in GSM 900 MHz and 1800 MHz, UMTS 900 MHz and 2100 MHz and for LTE 450 MHz, 700 MHz, 800 MHz, 900 MHz and 1800 MHz at 3000 m.

The analysis also concluded that registration to the ground network is not feasible for LTE 1800 MHz at altitudes of 4000 m and above. For the LTE frequencies 2100 MHz and above registration to the ground network is not possible at altitudes of 3000 m and above

5.2 CONNECTIVITY AND INTERFERENCE ANALYSIS

The impact of aggregate interference from terrestrial base station transmitters into an airborne user terminal receiver has been assessed for a number of frequency bands and cellular technologies. Initially, the variation of the received power at the airborne user terminal receiver has been examined as a function of the angle above the terrestrial base station transmit antenna horizon. The results of the initial analysis have been used to determine the key alignment angle where the received power at the airborne user terminal is maximum.

The modelling of interference has been undertaken by assuming that the victim link (between the terrestrial base station transmitter and the airborne user terminal receiver) is operating at the key alignment angle as determined in the initial analysis. The aggregate interference power has been calculated by assuming a number of tiers of interferers surrounding the victim link base station transmitter.

The calculated victim link received power, aggregate interference power and receiver noise level have been combined to determine the C/(N+I) ratio which is then compared against the C/(N+I) threshold.

The interference analysis has considered GSM, UMTS and LTE technologies and their relevant operating frequency bands ranging from 450 MHz to 2100 MHz. In the case of UMTS where the impact assessment is based on the ability to detect the pilot channels used to be able to register to the ground network, the implications of interfering base station traffic loading have been taken into account by varying the transmit power to account for 50% and 75% loading.

The analysis results show that:

- For LTE 450 and LTE 800 (based on -6 dB C/(N+I) threshold), if there is one tier of interferers (i.e. 6 base station sites each with 3 sectors) and the aircraft height is 5 km and above the connection with the airborne user terminal is not sustainable. In the case of two tiers (i.e. 18 base station sites each with 3 sectors), the aircraft height of 3 km and above is sufficient to prevent communication;
- For LTE 1800 (based on -6 dB C/(N+I) threshold), one tier of interferers is sufficient to prevent communication with the airborne user terminal at 3 km height and above;
- For GSM 900 and GSM 1800 (based on 9 dB C/(N+I) threshold), one tier of interferers is sufficient to make the connection unsustainable with the airborne user terminal at 3 km height and above;
- For UMTS 900 (based on -20 dB C/(N+I) threshold), if there are six tiers of interferers (i.e. 126 base station sites each with 3 sectors) with 50% loading and an aircraft height is 5 km and above the link with the airborne user terminal cannot be established. When interfering base stations are 75% loaded four tiers of interferers and an aircraft height of 5 km and above are required to prevent a connection;
- For UMTS 2100 (based on -20 dB C/(N+I) threshold), six tiers of 50% loaded interferers are needed to prevent a connection with the airborne user terminal. Scenarios with 4 tiers (i.e. 60 base station sites each with 3 sectors) and 5 tiers (i.e. 90 base station sites each with 3 sectors) of 50% loaded interferers also make the connection unsustainable when the aircraft height is 5 km and above. In the case of 75% loaded interferers, two tiers of interferers is sufficient to make the victim link unsustainable when the aircraft height is 5 km and above;

- The C/(N+I) analysis generally concludes that no successful registration of user equipment onboard the aircraft is possible in any of the GSM and LTE frequencies considered. However, under specific circumstance, such as edge of network coverage (for example coastlines), the analysis indicates that connectivity may be possible. For UMTS frequency bands considered, the analysis indicates that successful registration of user equipment onboard is possible. At 10 km, however, the signal levels received by the onboard ac-MS receiver are at the C/I limit for the user equipment;
- The results of the analysis identify that ac-MS transmissions in the absence of an NCU negatively impact the performance of ground based UMTS networks. Actual degradation will vary according to interference environments (for example, network response, traffic model and distribution, UE deployments, terrain, etc.).

The modelling results are corroborated by the analysis undertaken using BS deployment data recorded in the French database of macro BS deployments.

The different results for GSM / LTE and UMTS can be explained by the different protection criteria for interference for the different technologies. The SINR studies considered the degradation in C/(N+I) resulting from interference in the uplink and downlink. For UMTS a C/(N+I) of -20 dB was assumed, for LTE a value of -6dB was used, and for GSM a value of 9 dB was used.

It is recommended, therefore, that the regulatory framework be updated to reflect that the usage of the NCU is made optional for all GSM and LTE frequency bands, and that for UMTS that User Equipment onboard be prevented from attempting to access networks on the ground. This could be ensured:

- by the inclusion of a Network Control Unit (NCU), which raises the noise floor inside the cabin in mobile receive bands;

  and/or

- through aircraft fuselage attenuation to further attenuate the signal entering and leaving the fuselage.

5.3 OTHER CONSIDERATIONS REGARDING FUTURE TECHNOLOGIES FOR 5G

Future technologies related to 5G would likely involve frequency and time multiplexing access schemes for the transmission and the reception of UE and BS, similarly to GSM and LTE, unlike UMTS[13]. Without precluding the frame structure, the waveform, the signalling procedures applicable to 5G systems, it can be expected, therefore, that the usage of the NCU is not necessary to cover frequency bands employed by future 5G terrestrial networks.

[13] Based on a Code Division Multiple Access technique.

ANNEX 1: CEPT MANDATE [1]

EUROPEAN COMMISSION
Directorate-General for Communications Networks Content and Technology

The Director General

Brussels, 07 October 2015
DG CONNECT/B4

Mandate to CEPT to undertake technical studies regarding the possibility of making the usage of the Network Control Unit (NCU) optional onboard MCA enabled aircraft

1. Purpose

The purpose of this mandate is to study the possibility of making the usage of the Network Control Unit (NCU) optional within Mobile Communications onboard Aircraft (MCA), in order to satisfy the EU policy objectives listed below.

The NCU is part of the MCA onboard system. It is designed to ensure that signals transmitted by ground-based mobile systems are not detectable within the aircraft cabin and that the user terminals on the aircraft only transmit at a minimum level so that they only register with the onboard Base Station.

MCA providers have argued that a technical solution based just on the onboard Base Station would be sufficient to prevent mobile devices from attempting connections to the ground. According to this assumption, the benefits of the NCU would be negligible. Enabling MCA systems without NCU would make the system simpler and cheaper, thus favouring a broader adoption of MCA and therefore reducing the number of "uncontrolled" active mobile devices. It must also be considered that the NCU, which deliberately creates electromagnetic noise in a number of frequencies, is itself a potential source of interference.

2. EU Policy objectives

Better regulation: the EU has taken the engagement to design policies and laws so that they achieve their objectives at minimum cost. This ensures that policy is prepared, implemented and reviewed in an open, transparent manner, informed by the best available evidence and backed up by involving stakeholders. To ensure that EU action is effective, the Commission assesses the expected and actual impacts of policies, legislation and other important measures at every stage of the policy cycle - from planning to implementation, to review and subsequent revision.

Competitiveness: should technical studies prove that the MCA services without NCU could coexist with terrestrial mobile networks, imposing the installation and periodical upgrade or substitution of such a component on the whole fleet of MCA enabled aircraft would constitute an undue hindrance to competitiveness.

Socioeconomic dimension: Simplifying and making less expensive the requirements for MCA operation contributes to a wider and faster adoption of aeroconnectivity systems, therefore enabling a wider number of citizens to remain connected when they travel.

3. Justification

Commission Decision 2008/294/EC of 7 April 2008 on harmonised conditions of spectrum use for the operation of mobile communication services on aircraft (MCA services) in the Community, as modified by Commission Implementing Decision 2013/654/EU[1], foresees the obligation to install a Network Control Unit[2] in all MCA enabled aircraft.

Implementing Decision 2013/654/EU imposes, *inter alia*, the upgrading of NCUs in order to cover new terrestrial mobile frequencies. This involves several steps including the design, certification, airworthiness certification, marketing and installation (which can be done only in the occasion of major aircraft maintenance overhauls). Therefore, in Decision 2013/654/EU, Article 2 granted a delay for the application of the new NCU parameters on the 2.6 GHz frequency band *until 1 January 2017*.

Meanwhile, at this stage, no interference case has been reported to or from terrestrial wireless systems. Furthermore, every day some mobile terminals are inadvertently left in "transmit" mode in "non-connected" aircraft. It should however be reminded that the sources of interferences (as well as of any signalling issues) on mobile networks are more and more difficult to detect. Considering the above mentioned deadline of 1 January 2017, and the industrial, operational and administrative timing linked to the possible future implementation of updated Network Control Units, there is the need for a tight timing of the assessment of the current approach.

Pursuant to Article 4(2) of the Radio Spectrum Decision[3] the Commission may issue mandates to the CEPT for the development of technical implementing measures with a view to ensuring harmonised conditions for the availability and efficient use of radio spectrum necessary for the functioning of the internal market. Such mandates shall set the tasks to be performed and their timetable.

Therefore, the Commission considers that the request put forward by AeroMobile[4] in the context of consistent implementation of the RSPP objectives of efficient management and use of spectrum, bridging the digital divide, enabling the Union to take the lead in wireless electronic communications, promoting innovation, developing effective competition, avoiding harmful interference and disturbance and fostering the accessibility of new consumer products and technologies, justify the need for technical studies to identify the possibility to make Network Control Units optional in the framework of Mobile Communications onboard Aircraft (MCA).

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[1] Commission Implementing Decision 2013/654/EU, of 12 November 2013, amending Decision 2008/294/EC to include additional access technologies and frequency bands for mobile communication services on aircraft (MCA services). OJ L303, 14.11.2013, p.48

[2] According to Article 2 (4) of Decision 2008/294/EC, "*network control unit (NCU) means equipment to be located in the aircraft that ensures that signals transmitted by ground-based mobile electronic communication systems listed in Table 2 in the Annex are not detectable within the cabin by raising the noise floor inside the cabin in mobile communication receive bands*".

[3] Decision 676/2002/EC of the European Parliament and of the Council of 7 March 2002 on a regulatory framework for radio spectrum policy in the European Community, OJL 108 of 24.4.2002

[4] Aeromobile White Paper: RSCOM 15-24.

4. Task order and schedule

CEPT is herewith mandated to undertake work to determine the possibility to make the installation of a Network Control Unit onboard MCA equipped aircraft optional.

The work will need to verify that a MCA configuration without NCU is sufficient to guarantee a reasonable protection against interferences and signalling issues to and from terrestrial wireless telecommunication systems. The term "reasonable" must be seen in the light of "real life operations" keeping account of the fleet mix (MCA and non MCA equipped aircraft, number of mobile terminals which remain operational also in non MCA equipped aircraft, etc.).

In the work carried out under the Mandate, the general and specific policy objectives of the RSPP, such as effective and efficient spectrum use and the support for specific Union policies shall be given utmost consideration. In implementing this mandate, CEPT shall, where relevant, take utmost account of EU law applicable and support the principles of service and technological neutrality, non-discrimination and proportionality insofar as technically possible.

CEPT should provide deliverables under this Mandate according to the following schedule:

Delivery date	Deliverable	Subject
March 2016	Interim Report from CEPT to the Commission	Description of work undertaken and interim results.
June 2016	Final Draft Report from CEPT to the Commission	Description of work undertaken and final results subject to public consultation.
December 2016	Final Report from CEPT to the Commission, taking into account the outcome of the public consultation.	Description of work undertaken and final results.

CEPT is requested to report on the progress of its work pursuant to this Mandate to all meetings of the Radio Spectrum Committee taking place during the course of the Mandate.

The Commission, with the assistance of the Radio Spectrum Committee and pursuant to the Radio Spectrum Decision, may consider applying the results of this mandate in the EU, pursuant to Article 4 of the Radio Spectrum Decision.

ANNEX 2: TECHNICAL PARAMETERS

A2.1.1 Antenna Model

ITU-R Recommendation F.1336-4 [9] is used to model all base station antennas with the following assumptions:

- Improved peak sidelobe pattern was used for MCL calculations;
- Improved average sidelobe pattern was used for all C/(N+I) calculations;
- Parameters K_a, K_p, K_h are set to 0.7 and the parameters K_v is set to 0.3;
- 65 degrees sector antenna with 3 dB beamwidth.

A2.1.2 GSM Parameters

The parameters listed in Table 45 are applicable to GSM technology operating in the 900 MHz and 1800 MHz bands and have been used in the calculations:

Table 45 : Parameters for GSM900 and GSM1800

Parameters	GSM900		GSM1800		Reference
	BS	MS	BS	MS	
Antenna input power (dBm/channel)	43	33	43	30	ECC Report 93 [7]
Receiver bandwidth (MHz)	0.2	0.2	0.2	0.2	ECC Report 93
Antenna gain (dBi)	15	0	18	0	ECC Report 93
Antenna height (m)	30	Aircraft height above ground	30	Aircraft height above ground	ECC Report 93
Electrical antenna downtilt (degrees)	3	N/A	3	N/A	
Feeder Loss (dB)	0	N/A	0	N/A	
Noise figure (dB)	4	7	4	7	ECC Report 93
Receiver noise floor [18] (dBm/channel)	-117	-114	-117	-114	
Body loss (dB)	0	4	0	4	ITU-R Report M.2292 [13]
Reference receiver sensitivity (dBm/channel)	-104	-102	-104	-102	ECC Report 93
Co-channel interference criterion	C/(N+I)=9 dB				ECC Report 93
Aircraft attenuation (dB)	5				ECC Report 93
Cell radius (km)	5 (1800 MHz) / 8 (900 MHz)				ITU-R Report M.2292
Reuse sites (RS) (km)	7[19]				
Intersite distance	1.5 * √RS *cell radius[20]				ITU-R Report M.2292
Cell loading	N/A				

[18] Receiver noise floor =10$\log_{10}$ (K*T*B) + 30 + Noise figure, where K is Boltzmann's constant (1.3804*10^{-23}), T is the ambient temperature (290 K), and B is the bandwidth (Hz).
[19] RS = 7 is number of tri-sector sites (21 frequencies total, 3 sectors per site)
[20] Where is the frequency re-use cell re-use pattern for GSM in line with ECC Report 93 (i.e. 7 or 13).

A2.1.3 UMTS Parameters

The parameters listed in Table 46 are applicable to UMTS technology for the 900 MHz and 2100 MHz bands and have been used in the calculations:

Table 46: Parameters for UMTS900 and UMTS2100

Parameters	UMTS900		UMTS2100		Reference
	BS	MS	BS	MS	
Antenna input power (dBm/channel)	33[21]	21/24[22]	33	21/24	ECC Report 93 [7] ETSI TS 125 101 [15] V12.6.0
Receiver bandwidth (MHz)	3.84	3.84	3.84	3.84	ITU-R Report M.2039-3 [12] ECC Report 93
Antenna gain (dBi)	15	-3	18	-3	ITU-R Report M.2039-3 (900MHz), ECC Report 187 [8] (2100MHz),
Antenna height (m)	30	Aircraft height above ground	30	Aircraft height above ground	ITU-R Report M.2039-3 ECC Report 93
Electrical antenna downtilt (degrees)	3	N/A	3	N/A	ITU-R Report M.2039-3 ECC Report 93
Feeder Loss (dB)	0	N/A	0	N/	
Noise figure (dB)	5	9	5	9	ITU-R Report M.2039-3
Receiver noise floor (dBm/channel)	-103.13	-99.13	-103.13	-99.13	-
Body loss (dB)	0	4	0	4	ITU-R Report M.2039-3 ECC Report 237 [22]
Reference receiver sensitivity (dBm/channel)	-121	-114	-121	-117	ETSI TS 125 104 [16] V12.4.0, ETSI TS 125 101 V12.6.0
Co-channel interference criterion	C/(N+I)=-20dB (CPICH)				3GPP TS25.133 [19] V12.8
Aircraft attenuation	5dB				ECC Report 93
Cell radius	4(2100 MHz) / 8 km (900 MHz)				ITU-R Report M.2292 [13]
Intersite distance	1.5 x cell radius[23]				ITU-R Report M.2292
Cell loading (traffic)	50%(36dBm), 75% (39dBm)				

[21] Value quotes typical operator power levels for the UMTS pilot channel = max Input power (43 dBm) -10 dB = 33dBm (see Section 6.1 of ECC Report 093). In order to be able to register to the ground network, the MS should be able to decode the pilot channel.
[22] Note that 24 dBm/channel was used in the calculations.
[23] Assume frequency re-use factor of 1 for LTE and UMTS.

A2.1.4 LTE Parameters

The parameters listed in Table 47 are applicable to LTE technology for the 450 MHz, 700 MHz, 800 MHz, 900 MHz, 1800 MHz, 2100 MHz, 2300 MHz, 2600 MHz, 3500 MHz, and 3700 MHz bands and have been used in the calculations:

Table 47: Parameters for LTE 450/700/800/900/1800/2100/2300/2600/3500/3700

<table>
<tr><th rowspan="2">Parameters</th><th colspan="2">LTE450/700/800/900</th><th colspan="2">LTE1800/2100/2300/ 2600/3500/3700</th><th rowspan="2">Reference</th></tr>
<tr><th>BS</th><th>MS</th><th>BS</th><th>MS</th></tr>
<tr><td>Antenna input power (dBm/channel)</td><td>46[24]</td><td>23</td><td>46</td><td>23</td><td>ITU-R Report M.2292 [13]</td></tr>
<tr><td>Receiver bandwidth (MHz)</td><td>9</td><td>9</td><td>9</td><td>9</td><td>3GPP TS 36.104 [17] (V12.5.0),
3GPP TS 36.101 [18] (V12.5.0)</td></tr>
<tr><td>Antenna gain (dBi)</td><td>15</td><td>-3</td><td>18</td><td>-3</td><td>ITU-R Report M.2292</td></tr>
<tr><td>Antenna height (m)</td><td>30</td><td>Aircraft height above ground</td><td>30</td><td>Aircraft height above ground</td><td>ECC Report 93 [7],
ITU-R Report M.2292</td></tr>
<tr><td>Electrical Antenna downtilt (degrees)</td><td>3</td><td>N/A</td><td>3</td><td>N/A</td><td>ECC Report 93,
ITU-R Report M.2292</td></tr>
<tr><td>Feeder loss dB)</td><td>0</td><td>N/A</td><td>0</td><td>N/A</td><td></td></tr>
<tr><td>Noise figure (dB)</td><td>5</td><td>9</td><td>5</td><td>9</td><td>ITU-R Report M.2292</td></tr>
<tr><td rowspan="2">Receiver noise floor (dBm/channel)</td><td>-99.4 (LTE 700/800)</td><td>-95.4 (LTE 700/800)</td><td rowspan="2">-99.4</td><td rowspan="2">-95.4</td><td rowspan="2"></td></tr>
<tr><td>-102.4 (LTE 450/900)</td><td>-98.4 (LTE 450/900)</td></tr>
<tr><td>Body loss (dB)</td><td>0</td><td>4</td><td>0</td><td>4</td><td>ITU-R Report M.2292</td></tr>
<tr><td rowspan="5">Reference receiver sensitivity (dBm/channel)</td><td rowspan="5">-101.5</td><td>-90.5 (LTE 450)</td><td rowspan="5">-101.5</td><td>-94 (LTE 1800)</td><td rowspan="5">3GPP TS 36.104 (V12.5.0),
3GPP TS 36.101 (V12.5.0)</td></tr>
<tr><td>-95.5 (LTE 700)</td><td>-97 (LTE 2100)</td></tr>
<tr><td>-94 (LTE 800)</td><td>-97 (TDD-LTE 2300/2600)</td></tr>
<tr><td rowspan="2">-97 (LTE 900)</td><td>-95 (FDD-LTE 2600)</td></tr>
<tr><td>-96 (LTE 3500/3700)</td></tr>
<tr><td>Co-channel interference criterion</td><td colspan="4">C/(N+I)= -6dB (pilot)</td><td>ETSI TR 136 942 [23]V12</td></tr>
<tr><td>Aircraft attenuation</td><td colspan="4">5</td><td>ECC Report 93</td></tr>
</table>

[24] NOTE: In some bands the bandwidth is limited to 5 MHz, however, there is a corresponding reduction in transmitted power and improvement receiver sensitivity.

Parameters	LTE450/700/800/900	LTE1800/2100/2300/ 2600/3500/3700	Reference
(dB)			
Cell radius (km)	4 (f>2GHz) / 5 (1GHz<f<2GHz) / 8 (f<1GHz)		ITU-R Report M.2292
Intersite distance (km)	1.5 x cell radius		ITU-R Report M.2292
Cell loading (capacity and power)	50%, 100%		

ANNEX 3: INTERFERENCE ANALYSIS RESULTS

The results of the analysis obtained from SEAMCAT interference models are presented in the following tables for different frequency bands and cellular technologies.

The analysis used standard antenna modelling assumptions included in the SEAMCAT software (version 4).

Table 48: Interference analysis result (GSM 900 MHz, base station transmit frequency = 925 MHz, channel bandwidth = 200 kHz)

Aircraft Height (km)	Aircraft Loss (dB)	Maximum Receiver Wanted Power (C) (dBm in 200 kHz)	Noise Floor (N) (dBm in 200 kHz)	C/N (dB)	C/(N+I) criterion (dB)	Aggregate Interference Power (I) (dBm in 200 kHz) (1 tier)	Aggregate Interference Power (I) (dBm in 200 kHz) (2 tiers)	Aggregate Interference Power (I) (dBm in 200 kHz) (3 tiers)	C/(N+I) (1 tier)	C/(N+I) (2 tiers)	C/(N+I) (3 tiers)	Reference Sensitivity (Cmin) (dBm in 200 kHz)	Cmin/N (dB)
3	1	-68.45	-114	45.55	9	-63.72	-61.75	-60.8	-4.73	-6.70	-7.65	-102	12
3	5	-72.45	-114	41.55	9	-67.72	-65.75	-64.8	-4.73	-6.70	-7.65	-102	12
3	9	-76.45	-114	37.55	9	-71.72	-69.75	-68.8	-4.73	-6.70	-7.65	-102	12
5	1	-72.93	-114	41.07	9	-67.55	-64.27	-62.77	-5.38	-8.66	-10.16	-102	12
5	5	-76.93	-114	37.07	9	-71.55	-68.27	-66.77	-5.38	-8.66	-10.16	-102	12
5	9	-80.93	-114	33.07	9	-75.55	-72.27	-70.77	-5.38	-8.66	-10.16	-102	12
8	1	-77.03	-114	36.97	9	-72.6	-67.24	-64.94	-4.43	-9.79	-12.09	-102	12
8	5	-81.03	-114	32.97	9	-76.6	-71.24	-68.94	-4.43	-9.79	-12.09	-102	12
8	9	-85.03	-114	28.97	9	-80.6	-75.24	-72.94	-4.43	-9.79	-12.09	-102	12
10	1	-78.97	-114	35.03	9	-73.68	-68.61	-66.02	-5.29	-10.36	-12.95	-102	12
10	5	-82.97	-114	31.03	9	-77.68	-72.61	-70.02	-5.29	-10.36	-12.95	-102	12
10	9	-86.97	-114	27.03	9	-81.68	-76.61	-74.02	-5.29	-10.36	-12.95	-102	12

Table 49: Interference analysis result (GSM 1800 MHz, base station transmit frequency = 1805 MHz, channel bandwidth = 200 kHz)

Aircraft Height (km)	Aircraft Loss (dB)	Maximum Receiver Wanted Power (C) (dBm in 200 kHz)	Noise Floor (N) (dBm in 200 kHz)	C/N (dB)	C/(N+I) criterion (dB)	Aggregate Interference Power (I) (dBm in 200 kHz) (1 tier)	Aggregate Interference Power (I) (dBm in 200 kHz) (2 tiers)	Aggregate Interference Power (I) (dBm in 200 kHz) (3 tiers)	C/(N+I) (1 tier)	C/(N+I) (2 tiers)	C/(N+I) (3 tiers)	Reference Sensitivity (Cmin) (dBm in 200 kHz)	Cmin/N (dB)
3	1	-76.39	-114	37.61	9	-72.55	-68.63	-66.22	-3.84	-7.76	-10.17	-102	12
3	5	-80.39	-114	33.61	9	-76.55	-72.63	-70.22	-3.84	-7.76	-10.17	-102	12
3	9	-84.39	-114	29.61	9	-80.55	-76.63	-74.22	-3.84	-7.76	-10.17	-102	12
5	1	-80.87	-114	33.13	9	-73.96	-71.33	-69.32	-6.91	-9.54	-11.55	-102	12
5	5	-84.87	-114	29.13	9	-77.96	-75.33	-73.32	-6.91	-9.54	-11.55	-102	12
5	9	-88.87	-114	25.13	9	-81.96	-79.33	-77.32	-6.91	-9.54	-11.55	-102	12
8	1	-84.97	-114	29.03	9	-76.02	-73.24	-71.72	-8.95	-11.73	-13.25	-102	12
8	5	-88.97	-114	25.03	9	-80.02	-77.24	-75.72	-8.95	-11.73	-13.25	-102	12
8	9	-92.97	-114	21.03	9	-84.02	-81.24	-79.72	-8.95	-11.73	-13.25	-102	12
10	1	-86.91	-114	27.09	9	-76.89	-73.86	-72.33	-10.02	-13.05	-14.58	-102	12
10	5	-90.91	-114	23.09	9	-80.89	-77.86	-76.33	-10.02	-13.05	-14.58	-102	12
10	9	-94.91	-114	19.09	9	-84.89	-81.86	-80.33	-10.03	-13.05	-14.58	-102	12

Table 50: Interference analysis result (UMTS 900 MHz, base station transmit frequency = 925 MHz, channel bandwidth = 5 MHz) (Interfering base station power = 36 dBm, 50% cell loading)

Aircraft Height (km)	Aircraft Loss (dB)	Maximum Receiver Wanted Power (C) (dBm in 3.84 MHz)	Noise Floor (N) (dBm in 3.84 MHz)	C/N (dB)	C/(N+I) criterion (dB)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (1 tier)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (2 tiers)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (3 tiers)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (4 tiers)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (5 tiers)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (6 tiers)
3	1	-81.45	-99.13	17.68	-20	-74.05	-68.52	-66.44	-65.15	-64.32	-63.72
3	5	-85.45	-99.13	13.68	-20	-78.05	-72.52	-70.44	-69.15	-68.32	-67.72
3	9	-89.45	-99.13	9.68	-20	-82.05	-76.52	-74.44	-73.15	-72.32	-71.72
5	1	-85.93	-99.13	13.2	-20	-76.18	-72.51	-69.35	-67.64	-66.37	-65.48
5	5	-89.93	-99.13	9.2	-20	-80.18	-76.51	-73.35	-71.64	-70.37	-69.48
5	9	-93.93	-99.13	5.2	-20	-84.18	-80.51	-77.35	-75.64	-74.37	-73.48
8	1	-90.03	-99.13	9.1	-20	-78.47	-75.25	-73.17	-71.09	-69.45	-68.23
8	5	-94.03	-99.13	5.1	-20	-82.47	-79.25	-77.17	-75.09	-73.45	-72.23
8	9	-98.03	-99.13	1.1	-20	-86.47	-83.25	-81.17	-79.09	-77.45	-76.23
10	1	-91.97	-99.13	7.16	-20	-79.74	-76.33	-74.71	-72.79	-71.16	-69.85
10	5	-95.97	-99.13	3.16	-20	-83.74	-80.33	-78.71	-76.79	-75.16	-73.85
10	9	-99.97	-99.13	-0.84	-20	-87.74	-84.33	-82.71	-80.79	-79.16	-77.85

C/(N+I) (1 tier)	C/(N+I) (2 tiers)	C/(N+I) (3 tiers)	C/(N+I) (4 tiers)	C/(N+I) (5 tiers)	C/(N+I) (6 tiers)	Reference Sensitivity (Cmin) (dBm in 3.84 MHz)	Cmin/N (dB)
-7.41	-12.93	-15.01	-16.30	-17.13	-17.73	-114	-14.87
-7.43	-12.94	-15.02	-16.30	-17.13	-17.73	-114	-14.87
-7.48	-12.95	-15.02	-16.31	-17.14	-17.74	-114	-14.87
-9.77	-13.43	-16.58	-18.29	-19.56	-20.45	-114	-14.87
-9.80	-13.44	-16.59	-18.30	-19.57	-20.45	-114	-14.87
-9.89	-13.48	-16.61	-18.31	-19.57	-20.46	-114	-14.87
-11.60	-14.80	-16.87	-18.95	-20.58	-21.80	-114	-14.87
-11.65	-14.82	-16.89	-18.96	-20.59	-21.81	-114	-14.87
-11.79	-14.89	-16.93	-18.98	-20.61	-21.82	-114	-14.87
-12.28	-15.66	-17.28	-19.19	-20.82	-22.13	-114	-14.87
-12.35	-15.70	-17.30	-19.21	-20.83	-22.13	-114	-14.87
-12.53	-15.78	-17.36	-19.24	-20.85	-22.15	-114	-14.87

Table 51: Interference analysis result (UMTS 900 MHz, base station transmit frequency = 925 MHz, channel bandwidth = 5 MHz) (Interfering base station power = 39 dBm, 75% cell loading)

Aircraft Height (km)	Aircraft Loss (dB)	Maximum Receiver Wanted Power (C) (dBm in 3.84 MHz)	Noise Floor (N) (dBm in 3.84 MHz)	C/N (dB)	C/(N+I) criterion (dB)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (1 tier)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (2 tiers)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (3 tiers)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (4 tiers)	C/(N+I) (1 tier)	C/(N+I) (2 tiers)	C/(N+I) (3 tiers)	C/(N+I) (4 tiers)	Reference Sensitivity (Cmin) (dBm in 3.84 MHz)	Cmin/N (dB)
3	1	-81.45	-99.13	17.68	-20	-71.05	-65.52	-63.44	-62.15	-10.41	-15.93	-18.01	-19.30	-114	-14.87
3	5	-85.45	-99.13	13.68	-20	-75.05	-69.52	-67.44	-66.15	-10.42	-15.93	-18.01	-19.30	-114	-14.87
3	9	-89.45	-99.13	9.68	-20	-79.05	-73.52	-71.44	-70.15	-10.44	-15.94	-18.02	-19.31	-114	-14.87
5	1	-85.93	-99.13	13.2	-20	-73.18	-69.51	-66.35	-64.64	-12.76	-16.42	-19.58	-21.29	-114	-14.87
5	5	-89.93	-99.13	9.2	-20	-77.18	-73.51	-70.35	-68.64	-12.78	-16.43	-19.59	-21.29	-114	-14.87
5	9	-93.93	-99.13	5.2	-20	-81.18	-77.51	-74.35	-72.64	-12.82	-16.45	-19.59	-21.30	-114	-14.87
8	1	-90.03	-99.13	9.1	-20	-75.47	-72.25	-70.17	-68.09	-14.58	-17.79	-19.87	-21.94	-114	-14.87
8	5	-94.03	-99.13	5.1	-20	-79.47	-76.25	-74.17	-72.09	-14.61	-17.80	-19.87	-21.95	-114	-14.87
8	9	-98.03	-99.13	1.1	-20	-83.47	-80.25	-78.17	-76.09	-14.68	-17.84	-19.89	-21.96	-114	-14.87
10	1	-91.97	-99.13	7.16	-20	-76.74	-73.33	-71.71	-69.79	-15.25	-18.65	-20.27	-22.19	-114	-14.87
10	5	-95.97	-99.13	3.16	-20	-80.74	-77.33	-75.71	-73.79	-15.29	-18.67	-20.28	-22.19	-114	-14.87
10	9	-99.97	-99.13	-0.84	-20	-84.74	-81.33	-79.71	-77.79	-15.39	-18.71	-20.31	-22.21	-114	-14.87

Table 52: Interference analysis result (UMTS 2100 MHz, base station transmit frequency = 2110 MHz, channel bandwidth = 5 MHz) (Interfering base station power = 36 dBm, 50% cell loading)

Aircraft Height (km)	Aircraft Loss (dB)	Maximum Receiver Wanted Power (C) (dBm in 3.84 MHz)	Noise Floor (N) (dBm in 3.84 MHz)	C/N (dB)	C/(N+I) criterion (dB)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (1 tier)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (2 tiers)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (3 tiers)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (4 tiers)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (5 tiers)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (6 tiers)
3	1	-90.75	-99.13	8.38	-20	-77.76	-74.55	-73.28	-72.17	-71.2	-70.3
3	5	-94.75	-99.13	4.38	-20	-81.76	-78.55	-77.28	-76.17	-75.2	-74.3
3	9	-98.75	-99.13	0.38	-20	-85.76	-82.55	-81.28	-80.17	-79.2	-78.3
5	1	-95.22	-99.13	3.91	-20	-81.37	-77.42	-75.46	-74.29	-73.4	-72.69
5	5	-99.22	-99.13	-0.09	-20	-85.37	-81.42	-79.46	-78.29	-77.4	-76.69
5	9	-103.22	-99.13	-4.09	-20	-89.37	-85.42	-83.46	-82.29	-81.4	-80.69
8	1	-99.32	-99.13	-0.19	-20	-84.91	-80.6	-78.21	-76.62	-75.49	-74.68
8	5	-103.32	-99.13	-4.19	-20	-88.91	-84.6	-82.21	-80.62	-79.49	-78.68
8	9	-107.32	-99.13	-8.19	-20	-92.91	-88.6	-86.21	-84.62	-83.49	-82.68
10	1	-101.27	-99.13	-2.14	-20	-86.98	-82.43	-79.79	-77.99	-76.69	-75.76
10	5	-105.27	-99.13	-6.14	-20	-90.98	-86.43	-83.79	-81.99	-80.69	-79.76
10	9	-109.27	-99.13	-10.14	-20	-94.98	-90.43	-87.79	-85.99	-84.69	-83.76

C/(N+I) (1 tier)	C/(N+I) (2 tiers)	C/(N+I) (3 tiers)	C/(N+I) (4 tiers)	C/(N+I) (5 tiers)	C/(N+I) (6 tiers)	Reference Sensitivity (Cmin) (dBm in 3.84 MHz)	Cmin/N (dB)
-13.02	-16.22	-17.48	-18.59	-19.56	-20.46	-117	-17.87
-13.07	-16.24	-17.50	-18.60	-19.57	-20.46	-117	-17.87
-13.19	-16.29	-17.54	-18.63	-19.59	-20.49	-117	-17.87
-13.92	-17.83	-19.78	-20.94	-21.83	-22.54	-117	-17.87
-14.03	-17.87	-19.81	-20.97	-21.85	-22.55	-117	-17.87
-14.29	-17.98	-19.88	-21.02	-21.89	-22.59	-117	-17.87
-14.57	-18.78	-21.14	-22.72	-23.85	-24.66	-117	-17.87
-14.80	-18.87	-21.20	-22.76	-23.88	-24.68	-117	-17.87
-15.34	-19.09	-21.33	-22.85	-23.95	-24.74	-117	-17.87
-14.55	-18.93	-21.53	-23.31	-24.60	-25.53	-117	-17.87
-14.91	-19.07	-21.61	-23.36	-24.64	-25.56	-117	-17.87
-15.70	-19.39	-21.79	-23.49	-24.73	-25.63	-117	-17.87

Table 53: Interference analysis result (UMTS 2100 MHz, base station transmit frequency = 2110 MHz, channel bandwidth = 5 MHz) (Interfering base station power = 39 dBm, 75% cell loading)

Aircraft Height (km)	Aircraft Loss (dB)	Maximum Receiver Wanted Power (C) (dBm in 3.84 MHz)	Noise Floor (N) (dBm in 3.84 MHz)	C/N (dB)	C/(N+I) criterion (dB)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (1 tier)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (2 tiers)	Aggregate Interference Power (I) (dBm in 3.84 MHz) (3 tiers)	C/(N+I) (1 tier)	C/(N+I) (2 tiers)	C/(N+I) (3 tiers)	Reference Sensitivity (Cmin) (dBm in 3.84 MHz)	Cmin/N (dB)
3	1	-90.75	-99.13	8.38	-20	-74.76	-71.55	-70.28	-16.01	-19.21	-20.48	-117	-17.87
3	5	-94.75	-99.13	4.38	-20	-78.76	-75.55	-74.28	-16.03	-19.22	-20.48	-117	-17.87
3	9	-98.75	-99.13	0.38	-20	-82.76	-79.55	-78.28	-16.09	-19.25	-20.51	-117	-17.87
5	1	-95.22	-99.13	3.91	-20	-78.37	-74.42	-72.46	-16.89	-20.81	-22.77	-117	-17.87
5	5	-99.22	-99.13	-0.09	-20	-82.37	-78.42	-76.46	-16.94	-20.84	-22.78	-117	-17.87
5	9	-103.22	-99.13	-4.09	-20	-86.37	-82.42	-80.46	-17.07	-20.89	-22.82	-117	-17.87
8	1	-99.32	-99.13	-0.19	-20	-81.91	-77.6	-75.21	-17.49	-21.75	-24.13	-117	-17.87
8	5	-103.32	-99.13	-4.19	-20	-85.91	-81.6	-79.21	-17.61	-21.80	-24.15	-117	-17.87
8	9	-107.32	-99.13	-8.19	-20	-89.91	-85.6	-83.21	-17.90	-21.91	-24.22	-117	-17.87
10	1	-101.27	-99.13	-2.14	-20	-83.98	-79.43	-76.79	-17.42	-21.89	-24.51	-117	-17.87
10	5	-105.27	-99.13	-6.14	-20	-87.98	-83.43	-80.79	-17.61	-21.96	-24.54	-117	-17.87
10	9	-109.27	-99.13	-10.14	-20	-91.98	-87.43	-84.79	-18.06	-22.12	-24.64	-117	-17.87

Table 54: Interference analysis result (LTE 450, base station transmit frequency = 462.5 MHz, channel bandwidth = 10 MHz)

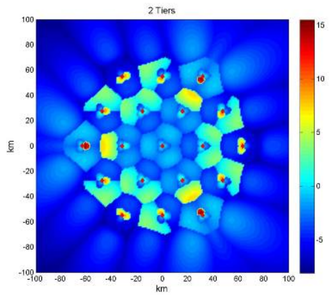
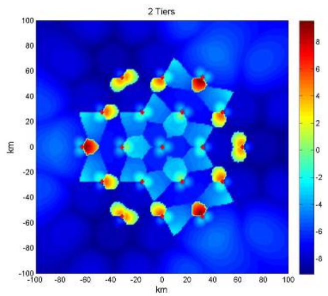
Aircraft Height (km)	Aircraft Loss (dB)	Maximum Receiver Wanted Power (C) (dBm in 10 MHz)	Noise Floor (N) (dBm in 10 MHz)	C/N (dB)	C/(N+I) criterion (dB)	Aggregate Interference Power (I) (dBm in 10 MHz) (1 tier)	Aggregate Interference Power (I) (dBm in 10 MHz) (2 tiers)	Aggregate Interference Power (I) (dBm in 10 MHz) (3 tiers)	C/(N+I) (1 tier)	C/(N+I) (2 tiers)	C/(N+I) (3 tiers)	Reference Sensitivity (Cmin) (dBm in 10 MHz)	Cmin/N (dB)
3	1	-62.43	-98.4	35.97	-6	-58.03	-52.5	-50.42	-4.40	-9.93	-12.01	-90.5	7.9
3	5	-66.43	-98.4	31.97	-6	-62.03	-56.5	-54.42	-4.40	-9.93	-12.01	-90.5	7.9
3	9	-70.43	-98.4	27.97	-6	-66.03	-60.5	-58.42	-4.40	-9.93	-12.01	-90.5	7.9
5	1	-66.9	-98.4	31.5	-6	-60.16	-56.49	-53.33	-6.74	-10.41	-13.57	-90.5	7.9
5	5	-70.9	-98.4	27.5	-6	-64.16	-60.49	-57.33	-6.74	-10.41	-13.57	-90.5	7.9
5	9	-74.9	-98.4	23.5	-6	-68.16	-64.49	-61.33	-6.74	-10.41	-13.57	-90.5	7.9
8	1	-71.01	-98.4	27.39	-6	-62.45	-59.23	-57.15	-8.56	-11.78	-13.86	-90.5	7.9
8	5	-75.01	-98.4	23.39	-6	-66.45	-63.23	-61.15	-8.56	-11.78	-13.86	-90.5	7.9
8	9	-79.01	-98.4	19.39	-6	-70.45	-67.23	-65.15	-8.57	-11.78	-13.86	-90.5	7.9
10	1	-72.95	-98.4	25.45	-6	-63.72	-60.31	-58.69	-9.23	-12.64	-14.26	-90.5	7.9
10	5	-76.95	-98.4	21.45	-6	-67.72	-64.31	-62.69	-9.23	-12.64	-14.26	-90.5	7.9
10	9	-80.95	-98.4	17.45	-6	-71.72	-68.31	-66.69	-9.24	-12.64	-14.26	-90.5	7.9

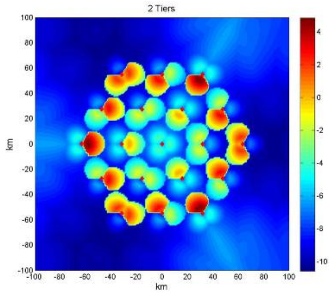
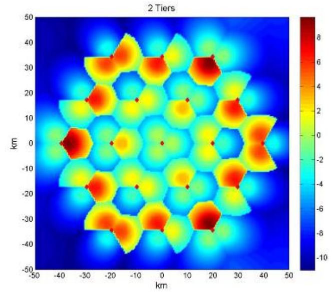
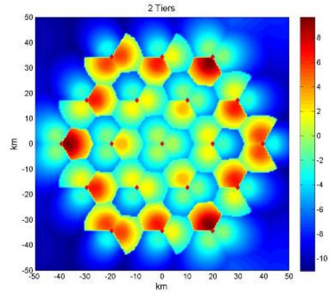
Table 55: Interference analysis result (LTE 800, base station transmit frequency = 791 MHz, channel bandwidth = 10 MHz)

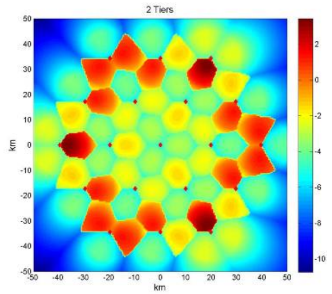
Aircraft Height (km)	Aircraft Loss (dB)	Maximum Receiver Wanted Power (C) (dBm in 9 MHz)	Noise Floor (N) (dBm in 9 MHz)	C/N (dB)	C/(N+I) criterion (dB)	Aggregate Interference Power (I) (dBm in 9 MHz) (1 tier)	Aggregate Interference Power (I) (dBm in 9 MHz) (2 tiers)	Aggregate Interference Power (I) (dBm in 9 MHz) (3 tiers)	C/(N+I) (1 tier)	C/(N+I) (2 tiers)	C/(N+I) (3 tiers)	Reference Sensitivity (Cmin) (dBm in 9 MHz)	Cmin/N (dB)
3	1	-67.09	-95.44	28.35	-6	-62.69	-57.16	-55.08	-4.40	-9.93	-12.01	-94	1.44
3	5	-71.09	-95.44	24.35	-6	-66.69	-61.16	-59.08	-4.41	-9.93	-12.01	-94	1.44
3	9	-75.09	-95.44	20.35	-6	-70.69	-65.16	-63.08	-4.41	-9.93	-12.01	-94	1.44
5	1	-71.57	-95.44	23.87	-6	-64.83	-61.15	-58	-6.74	-10.42	-13.57	-94	1.44
5	5	-75.57	-95.44	19.87	-6	-68.83	-65.15	-62	-6.75	-10.42	-13.57	-94	1.44
5	9	-79.57	-95.44	15.87	-6	-72.83	-69.15	-66	-6.76	-10.43	-13.57	-94	1.44
8	1	-75.67	-95.44	19.77	-6	-67.11	-63.89	-61.81	-8.57	-11.78	-13.86	-94	1.44
8	5	-79.67	-95.44	15.77	-6	-71.11	-67.89	-65.81	-8.58	-11.79	-13.86	-94	1.44
8	9	-83.67	-95.44	11.77	-6	-75.11	-71.89	-69.81	-8.60	-11.80	-13.87	-94	1.44
10	1	-77.61	-95.44	17.83	-6	-68.38	-64.97	-63.35	-9.24	-12.64	-14.26	-94	1.44
10	5	-81.61	-95.44	13.83	-6	-72.38	-68.97	-67.35	-9.25	-12.65	-14.27	-94	1.44
10	9	-85.61	-95.44	9.83	-6	-76.38	-72.97	-71.35	-9.28	-12.66	-14.28	-94	1.44

ANNEX 4: COMPREHENSIVE SINR MODELLING RESULTS

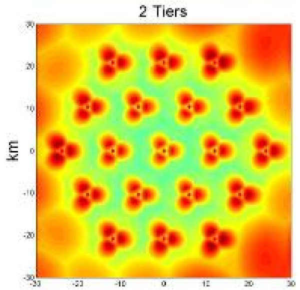
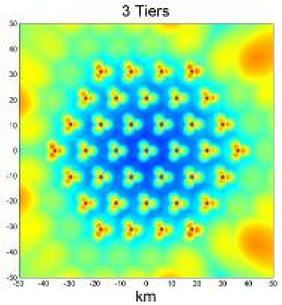
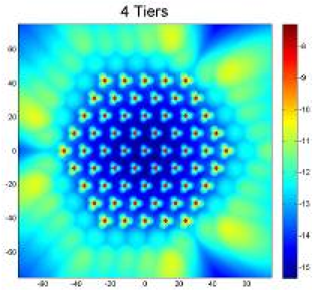
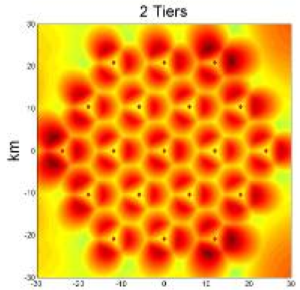
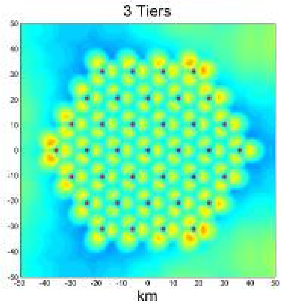
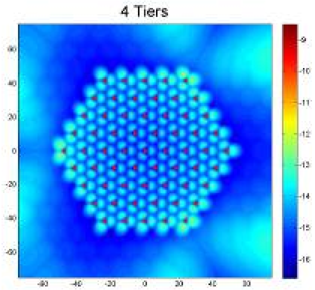
A4.1 GSM RESULTS

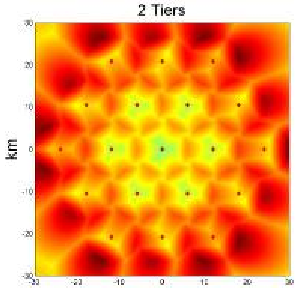
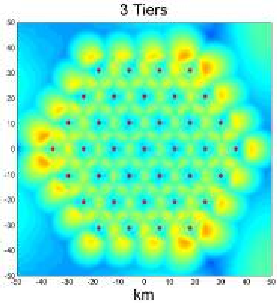
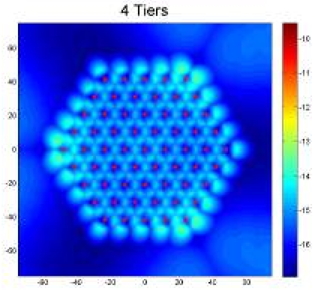
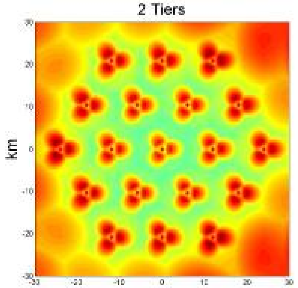
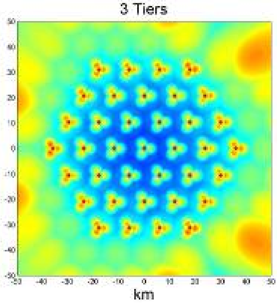
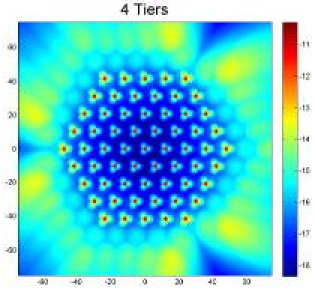
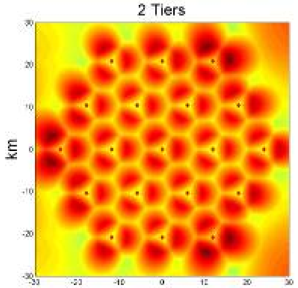
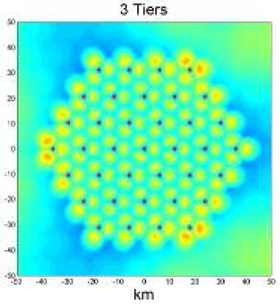
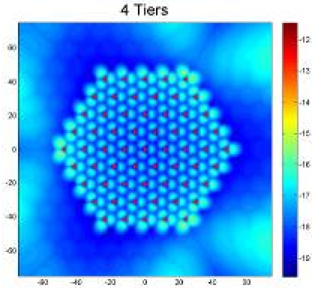
Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	No. Of tiers	Maximum SINR (dB)	SINR Graphic
GSM	900	8	3000	2	-0.1	
GSM	900	8	6000	2	-3.0	

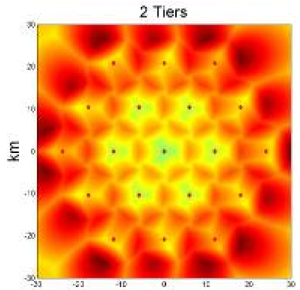
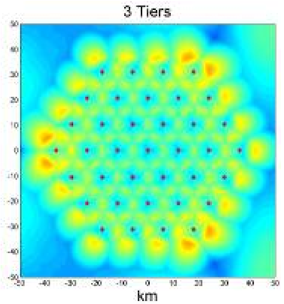
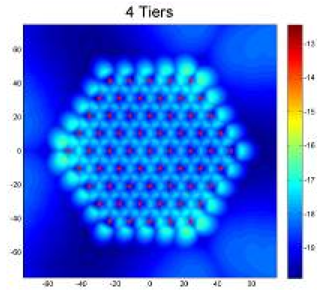
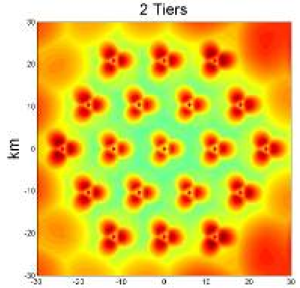
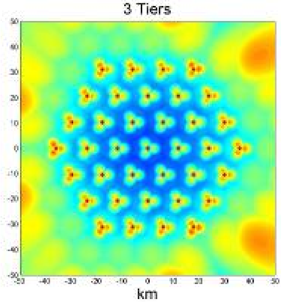
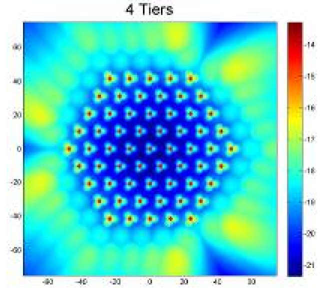
Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	No. Of tiers	Maximum SINR (dB)	SINR Graphic
GSM	900	8	10000	2	-3.7	
GSM	1800	5	3000	2	0.1	
GSM	1800	5	6000	2	-1.8	

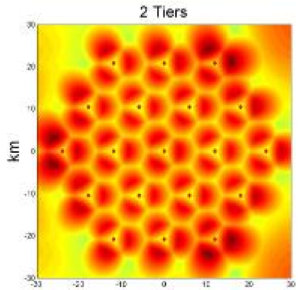
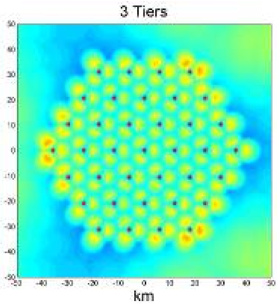
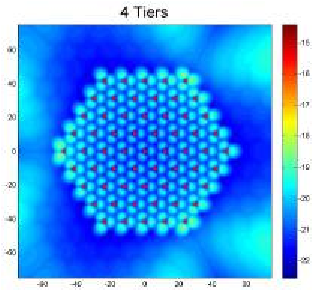
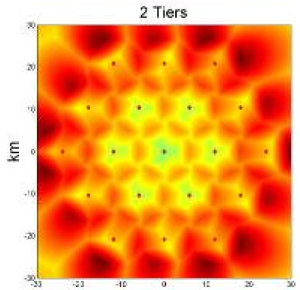
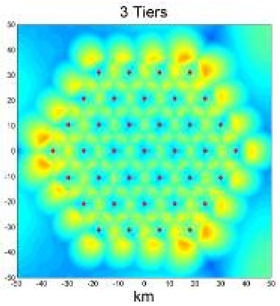
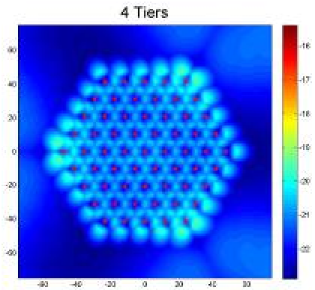
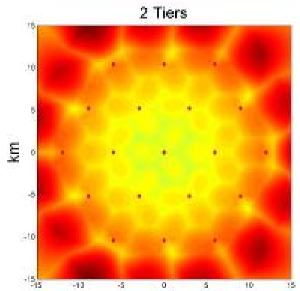
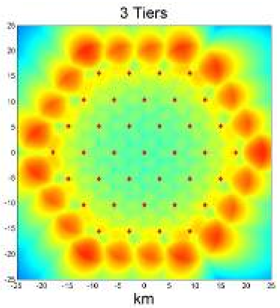
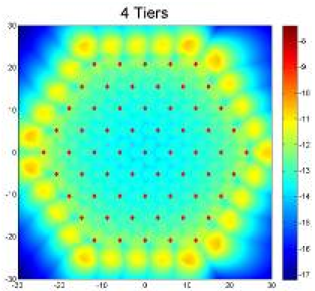
Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	No. Of tiers	Maximum SINR (dB)	SINR Graphic
GSM	1800	5	10000	2	-5.0	

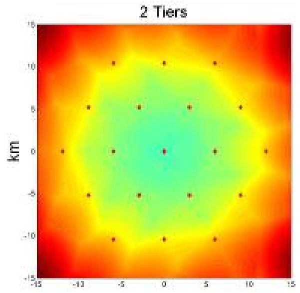
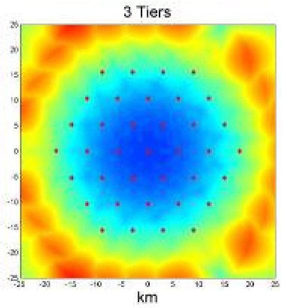
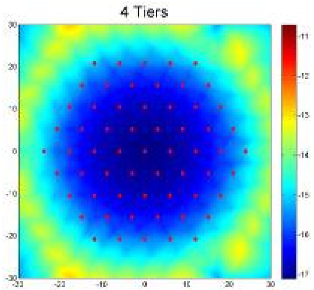
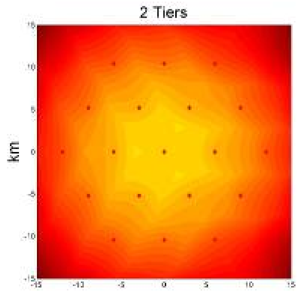
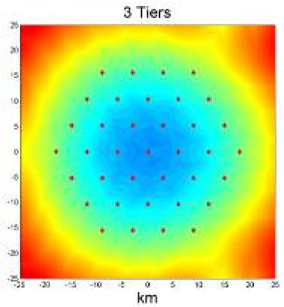
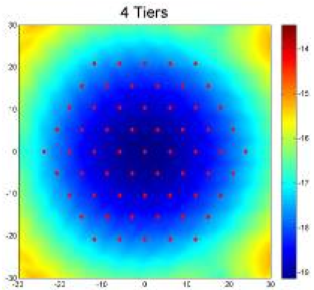
A4.2 UMTS RESULTS

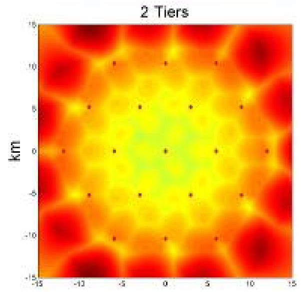
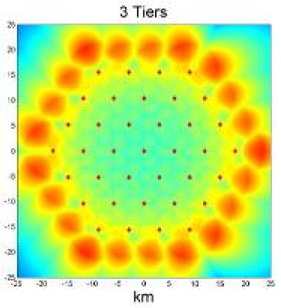
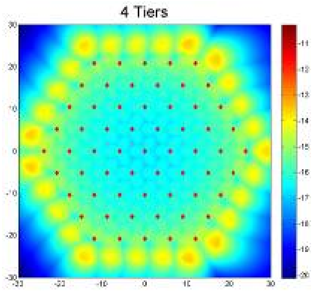
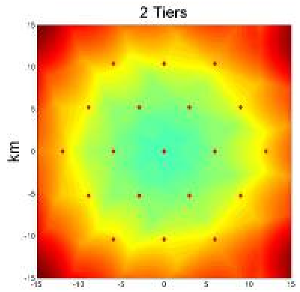
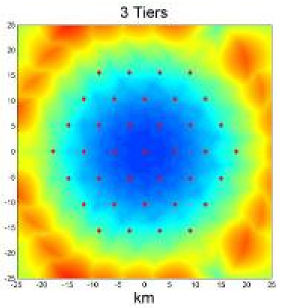
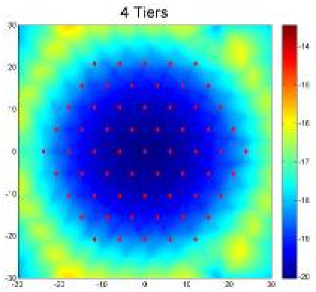
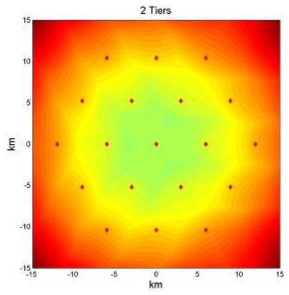
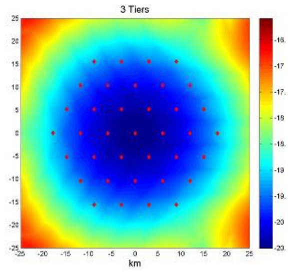
<table>
<tr><th rowspan="2">Technology</th><th rowspan="2">Band (MHz)</th><th rowspan="2">Cell Radius (km)</th><th rowspan="2">Altitude (m)</th><th rowspan="2">Cell Loading (%)</th><th colspan="3">SINR Graphic</th></tr>
<tr><th>2 Tiers</th><th>3 Tiers</th><th>4 Tiers</th></tr>
<tr><td rowspan="2">UMTS</td><td rowspan="2">900</td><td rowspan="2">8</td><td rowspan="2">3000</td><td rowspan="2">0</td><td></td><td></td><td></td></tr>
<tr><td>Max SINR = -8.3 dB</td><td>Max SINR = -10.6 dB</td><td>Max SINR = -12.1 dB</td></tr>
<tr><td rowspan="2">UMTS</td><td rowspan="2">900</td><td rowspan="2">8</td><td rowspan="2">6000</td><td rowspan="2">0</td><td></td><td></td><td></td></tr>
<tr><td>Max SINR = -9.2 dB</td><td>Max SINR = -11.7 dB</td><td>Max SINR = -13.7 dB</td></tr>
</table>

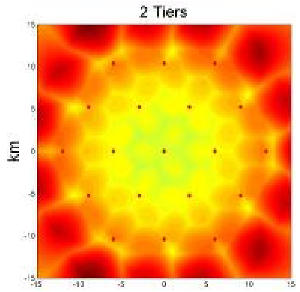
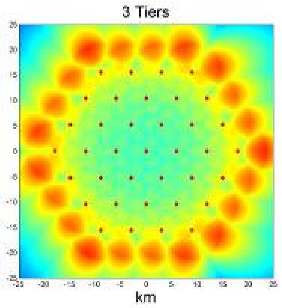
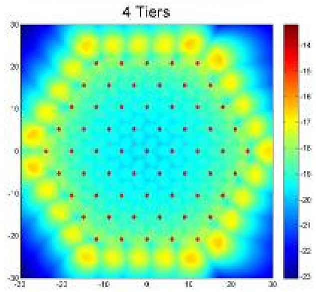
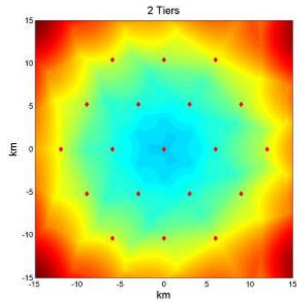
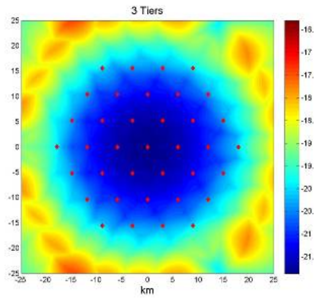
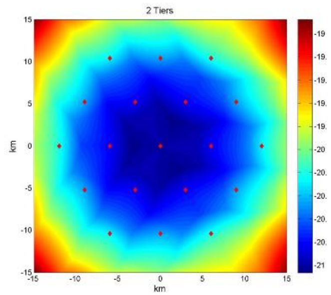
Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic 2 Tiers	3 Tiers	4 Tiers
UMTS	900	8	10000	0			
					Max SINR = -11.6 dB	Max SINR = -13.1 dB	Max SINR = -14.5 dB
UMTS	900	8	3000	50			
					Max SINR = -11.3 dB	Max SINR = -13.6 dB	Max SINR = -15.1 dB
UMTS	900	8	6000	50			

Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic 2 Tiers	3 Tiers	4 Tiers
					Max SINR = -12.2 dB	Max SINR = -14.7 dB	Max SINR = -16.7 dB
UMTS	900	8	10000	50			
					Max SINR = -14.5 dB	Max SINR = -16.1 dB	Max SINR = -17.5 dB
UMTS	900	8	3000	75			
					Max SINR = -14.3 dB	Max SINR = -16.6 dB	Max SINR = -18.1 dB

Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic		
					2 Tiers	3 Tiers	4 Tiers
UMTS	900	8	6000	75			
					Max SINR = -15.2 dB	Max SINR = -17.7 dB	Max SINR = -19.7 dB
UMTS	900	8	10000	75			
					Max SINR = -17.5 dB	Max SINR = -19.1 dB	Max SINR = -20.4 dB
UMTS	2100	4	3000	0			

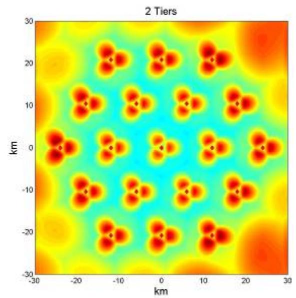
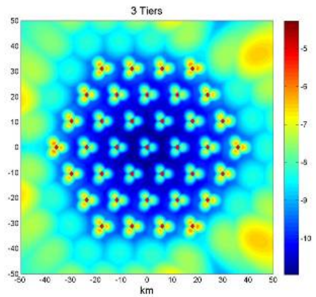
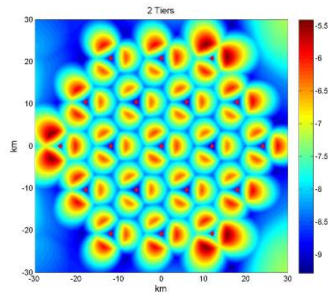
Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic 2 Tiers	3 Tiers	4 Tiers
					Max SINR = -11.2 dB	Max SINR = -12.5 dB	Max SINR = -14.5 dB
UMTS	2100	4	6000	0			
					Max SINR = -14.1 dB	Max SINR = -15.9 dB	Max SINR = -17.0 dB
UMTS	2100	4	10000	0			
					Max SINR = -15.4 dB	Max SINR = -17.6 dB	Max SINR = -19.1 dB

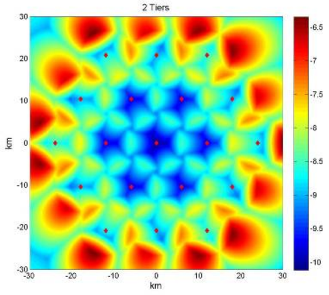
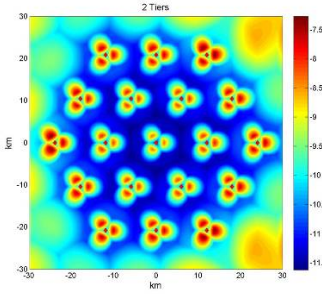
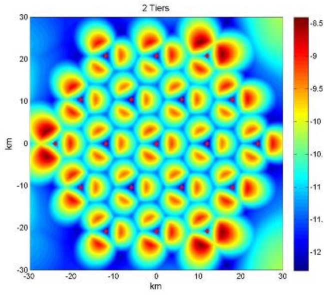
Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic 2 Tiers	SINR Graphic 3 Tiers	SINR Graphic 4 Tiers
UMTS	2100	4	3000	50			
					Max SINR = -14.1 dB	Max SINR = -15.5 dB	Max SINR = -16.4 dB
UMTS	2100	4	6000	50			
					Max SINR = -17.0 dB	Max SINR = -18.8 dB	Max SINR = -20.0 dB
UMTS	2100	4	10000	50			-
					Max SINR = -18.1 dB	Max SINR = -20.5 dB	-

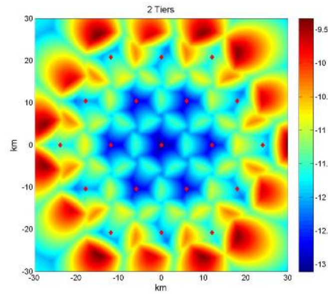
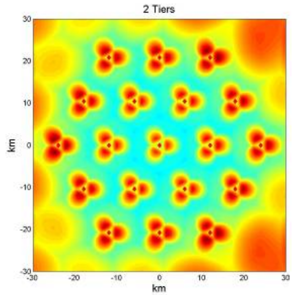
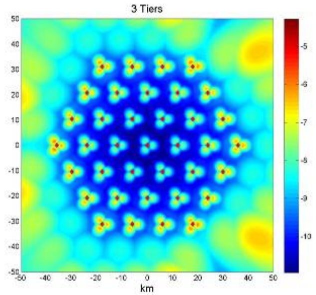
Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic		
					2 Tiers	3 Tiers	4 Tiers
UMTS	2100	4	3000	75			
					Max SINR = -17.1 dB	Max SINR = -18.5 dB	Max SINR = -19.4 dB
UMTS	2100	4	6000	75			-
					Max SINR = -20.0 dB	Max SINR = -21.8 dB	-
UMTS	2100	4	10000	75		-	-

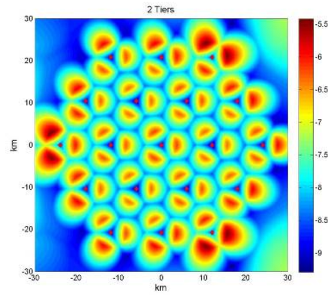
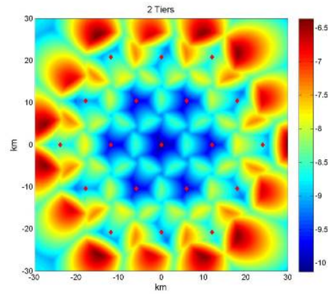
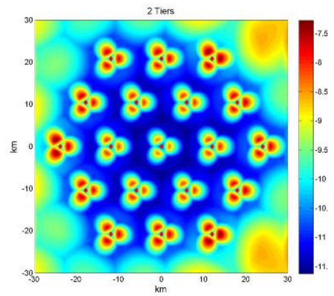
Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic 2 Tiers	 3 Tiers	 4 Tiers
					Max SINR = -21 dB	-	-

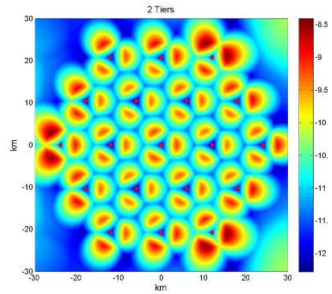
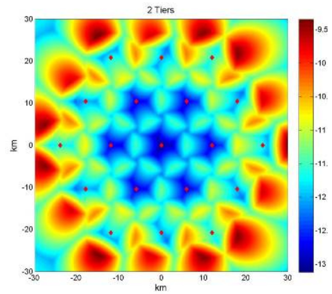
A4.3 LTE RESULTS

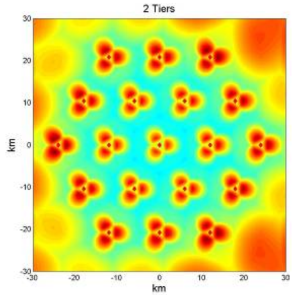
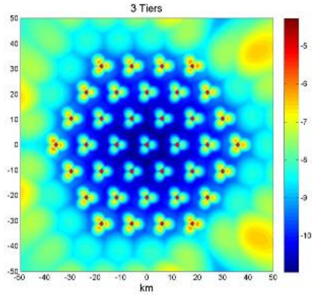
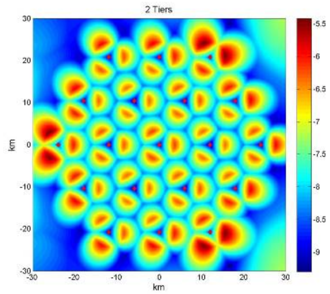
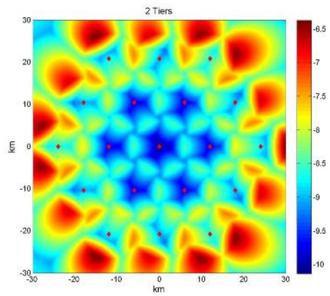
Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic 2 Tiers	 3 Tiers	 4 Tiers
LTE	450	8	3000	50			-
					Max SINR = -5.3 dB	Max SINR = -7.6 dB	-
LTE	450	8	6000	50		-	-
					Max SINR = -6.2 dB	-	-

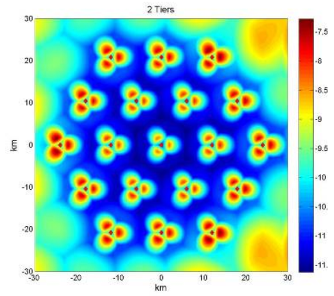
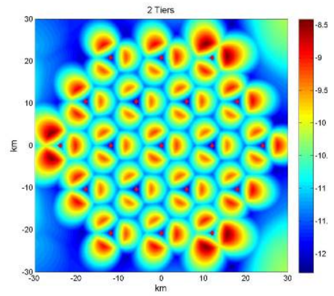
Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic 2 Tiers	3 Tiers	4 Tiers
LTE	450	8	10000	50		-	-
					Max SINR = -8.5 dB	-	-
LTE	450	8	3000	100		-	-
					Max SINR = -8.3 dB	-	-
LTE	450	8	6000	100		-	-

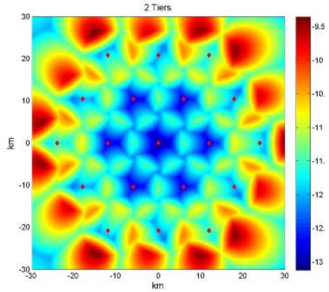
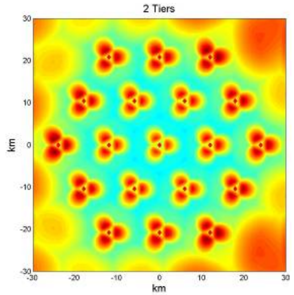
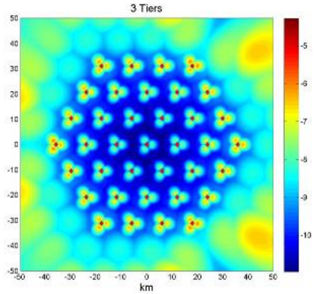
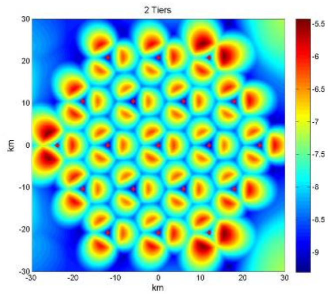
Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic 2 Tiers	3 Tiers	4 Tiers
					Max SINR = -9.2 dB	-	-
LTE	450	8	10000	100		-	-
					Max SINR = -11.5 dB	-	-
LTE	700	8	3000	50			-
					Max SINR = -5.3 dB	Max SINR = -7.6 dB	-

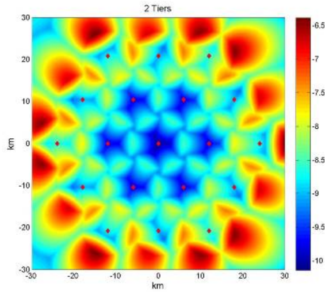
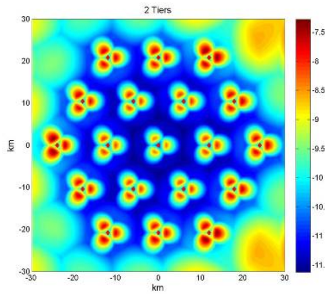
Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic		
					2 Tiers	3 Tiers	4 Tiers
LTE	700	8	6000	50		-	-
					Max SINR = -6.2 dB	-	-
LTE	700	8	10000	50		-	-
					Max SINR = -8.5 dB	-	-
LTE	700	8	3000	100		-	-

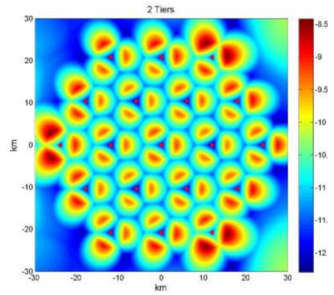
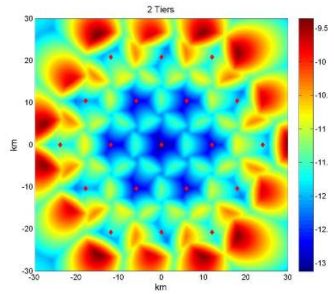
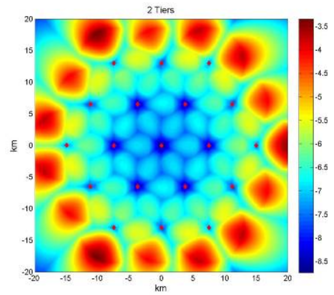
Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic 2 Tiers	3 Tiers	4 Tiers
					Max SINR = -8.3 dB	-	-
LTE	700	8	6000	100		-	-
					Max SINR = -9.2 dB		-
LTE	700	8	10000	100		-	-
					Max SINR = -11.5 dB	-	-

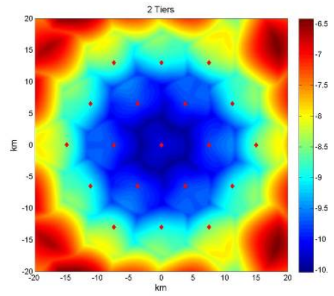
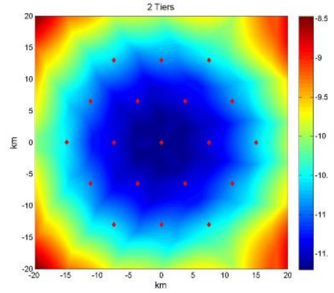
Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic		
					2 Tiers	3 Tiers	4 Tiers
LTE	800	8	3000	50			-
					Max SINR = -5.3 dB	Max SINR = -7.6	-
LTE	800	8	6000	50		-	-
					Max SINR = -6.2 dB	-	-
LTE	800	8	10000	50		-	-

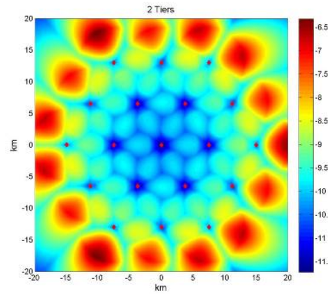
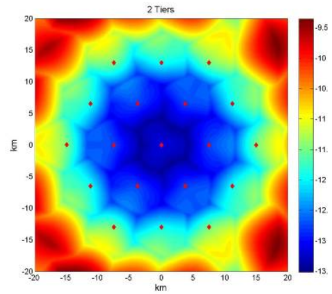
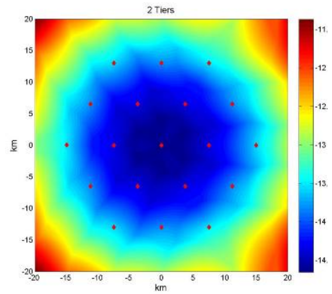
Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic		
					2 Tiers	3 Tiers	4 Tiers
					Max SINR = -8.5 dB	-	-
LTE	800	8	3000	100		-	-
					Max SINR = -8.3 dB	-	-
LTE	800	8	6000	100		-	-
					Max SINR = -9.2 dB	-	-

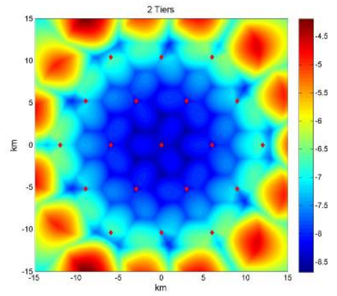
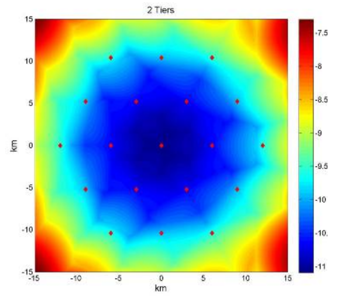
Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic 2 Tiers	 3 Tiers	 4 Tiers
LTE	800	8	10000	100		-	-
					Max SINR = -11.5 dB	-	-
LTE	900	8	3000	50			-
					Max SINR = -5.3 dB	Max SINR = -7.6 dB	-
LTE	900	8	6000	50		-	-

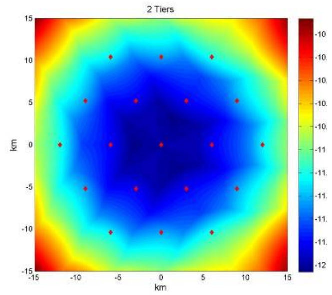
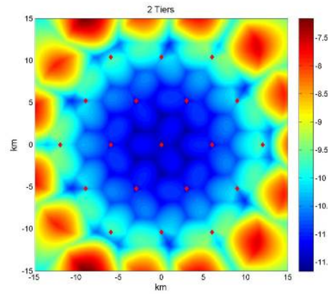
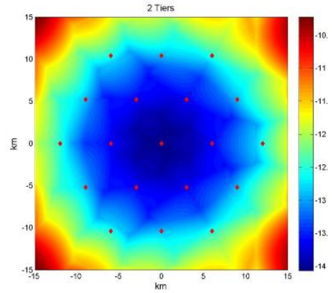
Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic 2 Tiers	3 Tiers	4 Tiers
					Max SINR = -6.2 dB	-	-
LTE	900	8	10000	50		-	-
					Max SINR = -8.5 dB	-	-
LTE	900	8	3000	100		-	-
					Max SINR = -8.3 dB	-	-

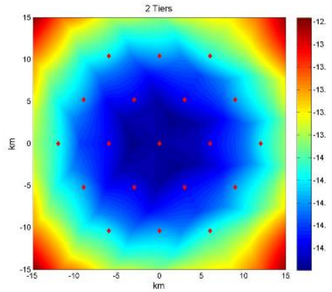
Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic 2 Tiers	3 Tiers	4 Tiers
LTE	900	8	6000	100		-	-
					Max SINR = -9.2 dB	-	-
LTE	900	8	10000	100		-	-
					Max SINR = -11.5 dB	-	-
LTE	1800	5	3000	50		-	-

Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic 2 Tiers	3 Tiers	4 Tiers
					Max SINR = -6.9 dB	-	-
LTE	1800	5	6000	50		-	-
					Max SINR = -10.2 dB	-	-
LTE	1800	5	10000	50		-	-
					Max SINR = -11.6 dB	-	-

Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic		
					2 Tiers	3 Tiers	4 Tiers
LTE	1800	5	3000	100		-	-
					Max SINR = -9.9 dB	-	-
LTE	1800	5	6000	100		-	-
					Max SINR = -13.2 dB	-	-
LTE	1800	5	10000	100		-	-

Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic 2 Tiers	 3 Tiers	 4 Tiers
					Max SINR = -14.6 dB	-	-
LTE	2100	4	3000	50		-	-
					Max SINR = -8.1 dB	-	-
LTE	2100	4	6000	50		-	-
					Max SINR = -10.9 dB	-	-

Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic		
					2 Tiers	3 Tiers	4 Tiers
LTE	2100	4	10000	50		-	-
					Max SINR = -12.0 dB	-	-
LTE	2100	4	3000	100		-	-
					Max SINR = -11.1 dB	-	-
LTE	2100	4	6000	100		-	-

Technology	Band (MHz)	Cell Radius (km)	Altitude (m)	Cell Loading (%)	SINR Graphic 2 Tiers	 3 Tiers	 4 Tiers
					Max SINR = -13.9 dB	-	-
LTE	2100	4	10000	100		-	-
					Max SINR = -14.9 dB	-	-

ANNEX 5: SPEED AND ALTITUDE STATISTICS FOR SEVERAL FRENCH FLIGHT ROUTES

Altitudes for various flights are depicted in below figures. The blue curve represents the altitude while the red one refers to the speed of the aircraft. Both parameters are used to compute the distance reached by the aircraft from the departure airport and then to derive the altitude of the aircraft for each point of the flight corridor.

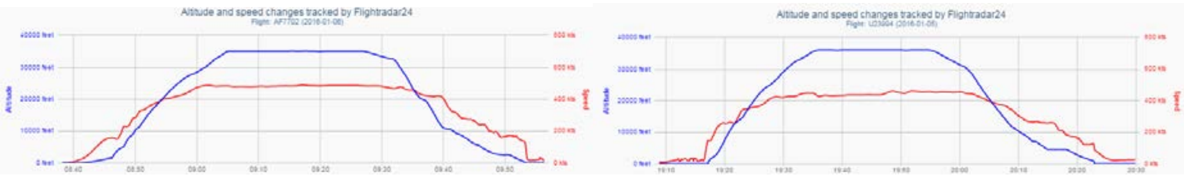


Figure 9: Air France CDG Paris to Nice (left side), Nice to Paris CDG (right side)

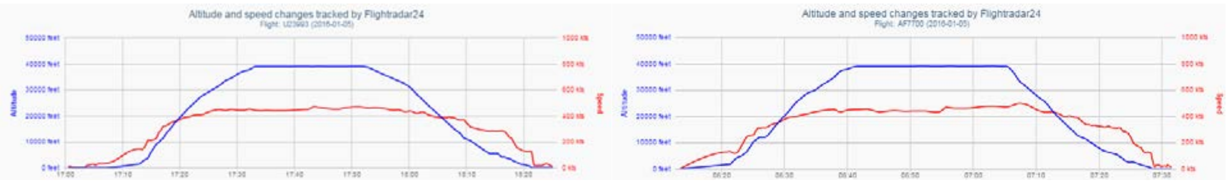


Figure 10: EasyJet CDG Paris to Nice (left side), Nice- to Paris CDG (right side)

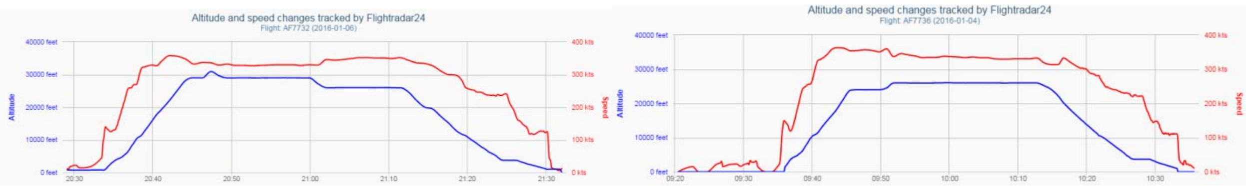


Figure 11: Air France CDG Paris to Brest (left side), Brest to Paris CDG (right side)

ANNEX 6: PROPOSED UPDATE OF THE EC REGULATORY TECHNICAL CONDITIONS IN EC DECISIONS 2008/294/EC [5] AND 2013/654/EC [6]

ANNEX

1. FREQUENCY BANDS AND SYSTEMS ALLOWED FOR MCA SERVICES

Table 1

Type	Frequency	System
GSM1800	1710-1785 MHz (uplink) 1805-1880 MHz (downlink)	GSM complying with the GSM Standards as published by ETSI, in particular EN 301 502, EN 301 511 and EN 302 480, or equivalent specifications.
UMTS 2100 (FDD)	1920-1980 MHz (uplink) 2110-2170 MHz (downlink)	UMTS complying with the UMTS Standards as published by ETSI, in particular EN301 908-1 EN 301 908-2, EN 301 908-3 and EN 301 908-11, or equivalent specifications.
LTE 1800 (FDD)	1710-1785 MHz (uplink) 1805-1880 MHz (downlink)	LTE complying with LTE Standards, as published by ETSI, in particular EN301 908-1, EN301 908-13, EN301 908-14, and EN301 908-15, or equivalent specifications.

2. PREVENTION OF CONNECTION OF MOBILE TERMINALS TO GROUND NETWORKS

During the period when operation of MCA services is authorised on an aircraft, mobile terminals receiving within the UMTS frequency bands listed in Table 2 must be prevented from attempting to register with mobile networks on the ground. This could be ensured:

- By the inclusion of a Network Control Unit (NCU), which raises the noise floor inside the cabin in mobile receive bands, and/or;
- Through aircraft fuselage attenuation to further attenuate the signal entering and leaving the fuselage.

MCA operators, at their discretion, may also choose to prevent terminals receiving within the non-UMTS frequency bands listed in Table 2.

Table 2

Frequency band (MHz)	Considered systems on the ground
460-470 MHz	LTE[25]
791-821 MHz	LTE
925-960 MHz	GSM, UMTS, LTE,
1805-1880 MHz	GSM, LTE
2110-2170 MHz	UMTS, LTE
2620-2690 MHz	LTE
2570-2620 MHz	LTE

[25] On a national level, administrations could use LTE technology for different applications such as BB-PPDR, BB-PMR or Mobile Networks

3. TECHNICAL PARAMETERS

(a) Equivalent isotropic radiated power (e.i.r.p.), outside the aircraft, from the NCU/aircraft BTS

Table 3

The total e.i.r.p., outside the aircraft, from the NCU/aircraft BTS/ aircraft Node B must not exceed:

Height above ground (m)	**Maximum e.i.r.p. the System outside the aircraft in dBm/channel**		
	NCU[1]	**Aircraft BTS**	**Aircraft BTS and NCU**
	Band: 900 MHz	**Band: 1800 MHz**	**Band: 2 GHz**
	Channel Bandwidth= 3.84 MHz	**Channel Bandwidth= 200 kHz**	**Channel Bandwidth= 3.84 MHz**
3000	-6.2	-13.0	1.0
4000	-3.7	-10.5	3.5
5000	-1.7	-8.5	5.4
6000	-0.1	-6.9	7.0
7000	1.2	-5.6	8.3
8000	2.3	-4.4	9.5

(b) Equivalent isotropic radiated power (e.i.r.p.), outside the aircraft, from the onboard terminal

Table 4

The e.i.r.p., outside the aircraft, from the mobile terminal must not exceed:

Height above ground (m)	**Maximum e.i.r.p., outside the aircraft, from the GSM mobile terminal in dBm/200 kHz**	**Maximum e.i.r.p., outside the aircraft, from the LTE mobile terminal in dBm/5 MHz**	**Maximum e.i.r.p., outside the aircraft, from the UMTS mobile terminal in dBm/3.84 MHz**
	GSM 1800 MHz	**LTE 1800 MHz**	**UMTS 2100 MHz**
3000	-3.3	1.7	3.1
4000	-1.1	3.9	5.6
5000	0.5	5	7
6000	1.8	5	7
7000	2.9	5	7
8000	3.8	5	7

(c) Operational requirements

I. The minimum height above ground for any transmission from an MCA system in operation must be 3000 metres.

II. The aircraft BTS, while in operation, must limit the transmit power of all *GSM* mobile terminals transmitting in the 1800MHz band to a nominal value of 0dBm/200 kHz at all stages of communication, including initial access.

III: The aircraft Node B, while in operation, must limit the transmit power of all *LTE* mobile terminals transmitting in the 1800MHz band to a nominal value of 5dBm/5MHz at all stages of communication.

IV. The aircraft Node B, while in operation, must limit the transmit power of all *UMTS* mobile terminals transmitting in the 2100 MHz band to a nominal value of -6dBm/3.84MHz at all stages of communication and the maximum number of users should not exceed 20.

ANNEX 7: LIST OF REFERENCE

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